BIOLOGY FOR BEGINNERS

Meant for Students of the Intermediate, Medical, Agriculture and Veterinary Courses

CENSORED AND PASSED
195
FOR D. I. G. I. B BENGAL.

BY

T. C. NANDI, M.Sc. (Botany), M.Sc. (Zoology),
Senior Professor of Biology, Bangabasi College and examiner, Calcutta University.

★ স্টাতি ★
1270
৫ জিহ্ব।ব।—৩৮

THE BOOK COMPANY, LTD
BOOKSELLERS AND PUBLISHERS,
4-3 B College Square Calcutta.

Published by
B. Nandi
of Messrs Nandi & Co.,
9, Hyat Khan Lane. Calcutta.

Second edition—revised & enlarged.

All rights reserv

Printed Sures C. Das, M.A.
binas· Press)
(General ters & Publishers Ltd.)
119, Dharamtala Street, Calcutta

PREFACE TO THE REVISED EDITION

The present edition is thoroughly revised and brought up-to-date, the diagrams of the botany part have been changed and some of the blocks of the zoology portion have also been changed.

The author humbly thanks Prof. Dr. J. C. Sengupta, Dr. G. P. Mazumdar, Dr. Kundu, Mr. K. G. Banerjee, Mr. H. Chakrabarty of Presidency College for various help. Thanks are also due to Prof. Dr. S. Sengupta, Dr. J Mukerjee, Mr. Das, Mr. P. Choudhury of Ripon College and to Prof. R. Sarker, Prof. Chatterjee of Ashutosh College.

I am also thankful to Mr. Sauren Banerjee for various help for improvement of this book. Sincere thanks are also due to Prof. Dr. T. N. Podder and Mr. Dhiren Chakraborty of Carmichael Medical College.

This book was so universally read by the Intermediate students for the last 8 years and with so very satisfactory results that the author feels encouraged to bring out a second edition, and hopes that it will prove equally useful to the novice and serve as an incentive to further study of the subject.

March, 1941. T. C. NANDI.

CONTENTS

PAGE

Preface . . . . [illegible]
General Introduction . . . . . . vii.
Living matter 1
Protoplasm 7
Cell 11
Tissue 19
Nutrition and growth 30
Chemical co-ordination 51
Reproduction 56
Organic evolution 70
Divisions of the plant kingdom . . . 86
Seeds 92
Roots 111
The shoot 123
Bud 134
Branching 138
Leaf 140
Inflorescence 157
Flower 164
Pollination and Fertilization 177
Fruit 181
Histology 187
Tissue system 210
Anatomy of plants . . . . . [illegible]
Cryptogams . . . . . . [illegible]
Classification of animals . . . [illegible]
Amœba

	PAGE
Monocystis	257
Hydra	261
Leech	269
Prawn	278
Bhetki	304
Toad	323
Guinea-pig	367

This little volume is humbly dedicated to Rector G. C. Bose of Bangabasi College as a token of gratitude for being my educational *"Guru"* and my father's too and also for his invaluable services as a *pioneer* in the cause of education in general and the spread of the *study of Botany* in particular.

ANGABASI COLLEGE.

AUTHOR.

PREFACE TO THE FIRST EDITION

Some apology for the appearance of a Book of Biology seems necessary; for in face of the multitude of its predecessors, the present volume can scarcely put forward the claim of supplying a "long-felt want."

The syllabus of the Calcutta University for intermediate course has been more than followed in order to make the student fit for a higher course of biology.

I make no shadow of a claim to having accomplished the task of producing an ideal text-book. Defects will be found but as it is the first venture where the subject has been dealt with at least on this part of our country, the author expects constructive criticism which will be gladly incorporated in the next edition.

If there is any merit in the botany portion that must be due to my teachers like Professors S. C. Banerjee, Late Dr. P. Bruhl, Late Professor S. C. Singha, G. P. Majumdar, K. G. Banerjee, Dr. S. P. Agharkar, I. Banerjee and J. Banerjee of Presidency College and University College of Science and for the Zoology portion my indebtedness will ever remain unredeemable to Professors Drs. H. K. Mookerjee, H. N. Roy, D. Roy Chowdhury of University College of Science and to Professors D. Mukherji and G. Chakrabarti of the same institution. But for the short-comings the poor author shoulders full responsibility.

The book has been prepared with the recent developments of the science in view but the standard has not been unduly burdened. As recently biology has been able to attract the attention of the directors of education of our country, it is expected the book will serve some useful purpose.

The book has been divided into two parts, of which the first part deals entirely with Botany and the second part deals with Zoology and comparative questions arising out of the syllabus. To be frank, I have consulted all the modern and current text-books on Botany and Zoology and I offer my grateful thanks to the authors of such text-books but let me assure readers that the compilation is not entirely the life-less echo of those volumes because local flora and fauna have been cited. The following books may be consulted by those who like to probe further into the subject. Strasburger's Text-book of Botany, Lawson's Text-book of Botany, Bose's Manual of Botany, Green's Vegetable Physiology, Palladin's Physiology, Parker & Bhatia's Text-book of Zoology, Lull's Organic evolution, Thomson's Manual of Zoology etc.

Finally, I express my sincerest reverence to my father Dr. D. C. Nandi who encouraged and helped me throughout my student-life. But for his unchangeable sympathy it would have been impossible for me to take my stand in the educational arena of my country.

My thanks are also due to Prof. A. Das Gupta, Prof. S. N. Banerjee and Mr. S. N. Nandi for various help and to Mr. Monoranjan Bannerjee for helping me with some of his blocks.

COURSE OF BIOLOGY FOR I.A. & I.Sc.

CALCUTTA UNIVERSITY

(1) Characteristics of the living matter. Difference between living and non-living. Difference between animal and plant..

(2) The physical and chemical nature of protoplasm (treated in an elementary manner). Cells, animal and vegetable, their structures and functions. Cell division. Tissues and tissue-systems in animals and plants.

(3) Nutrition and growth, circulation of nutritive materials, respiration, excretion, secretion and the storage of reserve material in animals and plants. Photosynthesis in plants.

(4) Stimulus and response in plants and animals. Movements in plants and animals. Nervous mechanism in animals.

(5) Chemical co-ordination.

(6) Reproduction, asexual and sexual. Parthenogenesis. Alternation of generation. The formation of the embryo in the fowl.

(7) Outlines of the theory of organic evolution.

(8) Elementary study of the following types:—

(*a*) Amœba, (*b*) Monocystis, (*c*) Hydra, (*d*) Leech, (*e*) the fresh water prawn, (*f*) Bhetki, (*g*) Toad, (*h*) Guineapig.

(*a*) Yeast, (*b*) Mucor, (*c*) Spirogyra, (*d*) Moss, (*e*) Fern, (*f*) Pea plant & (*g*) Maize plant.

might come to view. There are large animals and plants which we see around us but there are also others too small to be seen with the naked eye and requires the use of the compound microscope for their identification. The function of different organs and tissues of plants and animals is known as **Physiology.** The study of ascertaining their genetic relationships is **Systematic Botany.** It includes (1) **Nomenclature,** or the naming of plants, (2) **Taxonomy** or **Classification** means the grouping of plants according to differences and resemblances of morphological characters (**Principles**) and arranging them according to some definite plans (**Systems**). **Ecology** is the relation of plants and animals to environment. The above are but a few inportant branches of biology. Besides these, there are several other branches which deal with plants and animals of past geological periods (**Palaeontology**), diseases of living organisms (**Pathology**), study of heredity (**Genetics**) etc. The domain of Biology brings the resemblances and differences of animals and plants to the forefront after studying the life-histories of animals and plants. Biology has another important feature that it is able to bring out certain laws which govern the life of living organisms in this world.

It takes into consideration not only the organisms that are found to-day on the surface of the earth but also deals with organisms that once adorned the then world. Biology also deals with the *distribution* of plants and animals in the different countries of the world and the mysteries which explain the causation of such distribution on snow-clad mountain-tops and polar regions, as also dark fathomless sea-bottoms.

Importance of Biology—

Both plants and animals are of economic importance to man and so they will be dealt with side by side. Let us enumerate briefly some of the more important ways in which plants and animals contribute to our welfare or detract from it.

Plants :	Animals :
1. Foods derived from plants. The principal foods of all nations are derived directly from plants. Agriculture is the fundamental occupation of human beings, for of all living organisms green plants alone are able to organise the simple materials found in the air, water and soil into the complex substances which all plants and animals must have for food.	Foods derived from animals. Animal foods are of secondary importance and all animals live directly or indirectly upon plants. Meat, milk, butter etc. can be improved in quality and quantity if the animals are scientifically treated.
2. Fuel a plant product. Fuel is primarily supplied by plant. Wood is the universal source of heat and light energy. Coal, petroleum and natural gas, although obtained from the earth, are the products of plants which lived in former geological periods. When wood is burned, the great store of energy which the tree has accumulated from sunlight is	2. In India, the fæcal matter of cows is used in the form of dung-cakes as a form of fuel. The fats and oils of animals are also used for lighting purposes.

	set free in the form of heat. When coal, petroleum or natural gas is burned, the energy stored by plants from sunlight of former geological ages is liberated.		
3.	Plant fibres. These are used for clothing and many other articles. Cotton, jute, flax and hemp supply these fibres.	3.	*Animal fibres.*—These are also used for clothing as silk and wool.
4.	Wood products. Lumber is used for the construction of houses and buildings.	4.	Bones are used for various domestic purposes.
5.	Oils, resins and drugs.	5.	Animals supply glands for the preparation of medicines.
6.	Other uses of vegetation. Trees and grasses are great helpers for they retain water in soil, and prevent destructive erosion. Aquatic plants supply food to aquatic fauna.	6.	The earthworm of the soil does immense good by its burrowing habit by exposing the lower soil and taking the upper soil to lower levels.
7.	Importance of bacteria and fungi. Some bacteria and fungi help by bringing the decay of the dead bodies of animals and plants. Some bacteria help the digestion of animals.	7.	Some protozoa and other invertebrates cause disease in higher animals.
8.	Plants as a source of pleasure. Plants afford us an æsthetic pleasure.	8.	Animals like horse, cow, elephant, Camel, dog etc. are domesticated for immense help to human beings. Animals such as birds and butterflies etc. give us great pleasure.

CHAPTER I

CHARACTERISTICS OF THE LIVING MATTER

Living matter shows certain characteristics which mark them off from the **non-living.** Living matter essentially consists of a body composed of **protoplasm.** Even in the case of unicellular animal or plant, there must be *protoplasm.* Protoplasm has got complex chemical composition, namely, it is composed of proteins which are absent from the non-living matter. Living matter shows movement *i.e.,* capable of moving to and fro. This movement is more pronounced in the animal kingdom but not so in the plant kingdom but the roots of plants have to move constantly in search of food. Another factor peculiar to the living is the method of nutrition which means the taking in of food. The food is then digested with the help of certain juices known as digestive juices. Then absorption takes place and the animal grows. Growth as a result of nutrition and digestion is peculiar to the living. This type of growth is known as growth by intercalation. The plants take in inorganic salts in solution from the soil and organic food is prepared but that food has to be digested by plants. As a result of digestion, a plant grows. Therefore in the living, growth takes place as a result of internal process in other words, it is *intrinsic* but growth also takes place in the non-living which will be discussed in the course of this chapter.

Living matter is always undergoing loss of its substance but it is not visible because the loss is made good by nutrition. The loss is generally a process of oxidation. *i.e.*, combination with oxygen and as a result of this, energy is liberated which manifests itself in the activities of the organism. The process is called *respiration* which takes place both in animals and plants and externally oxygen is taken in and co_2 is given out.

The sum total of chemical changes as results of nutrition, digestion and respiration is known as *metabolism*. The constructive processes like nutrition and digestion are known as *Anabolism* whereas destructive processes like respiration, excretion are called *Katabolism*. Metabolism is the sum total of Anabolism and **Katabolism.**

Living matter shows *irritability i.e.*, it is capable of answering to external stimuli.

Over and above the power of responding to external stimuli, living matter has the power of automatic movement. This is known as automaticism.

Living matter ultimately attains old age, which is known as Senescence, and dies.

Reproduction *i.e.* to say bringing forth individuals similar to the parents is one of the most important manifestations of life. In fact, life from preexisting life is the rule in the living world, this is known as the law of biogenesis.

The above are the peculiarities of the living matter.

Difference between Living and Non-Living—

Living :	**Non-living :**
1. Presence of protoplasm.	1. Absence of protoplasm.
2. Nutrition occurs.	2. No nutrition.

3. Growth takes place by intercalation and intersusception of new materials.	3. Growth occurs simply by deposition or accretion of new materials on the outside.
4. Respiration and excretion occur.	4. No respiration or excretion.
5. Metabolic activities always present.	5. No metabolic activity.
6. Living matters are irritable and automatic.	6. Irritability is present upto a limited extent but automaticism is totally absent.
7. Reproduction occurs according to Biogenetic law.	7. No true reproductive activity.
8. Senescence and death occur.	8. There is no senile decay or death.

The points which have been noticed in the living are not found in the non-living but there are certain points which are common and require some special explanation. Growth takes place in the non-living also, as a stone by gradual collection of debris on it. They can form a larger lump but there is fundamental difference in the growth of non-living. This growth takes place not as a result of nutrition and digestion but on account of external deposit of lifeless matter. This is known as *extrinsic growth*.

Non-living matter does not show any protoplasm, or any method of organic reproduction, rhythmicity etc. In addition to the above, there are certain border-line cases which are hard to solve. A piece of sodium chloride is dead and a dog is living but when a piece of frog's muscle is kept in Ringer's solution and is capable of answering to stimulus we are confronted with the question that the frog as a unit is dead but the muscle is living or dead.

The answer can be given by bringing the characters of the living to its test.

Difference between Animal and Plant—

There are characters which are peculiar to plants while others are peculiar to animals but in the lowest groups they seem to merge with one another. Ordinarily, the source of organic food is the plant because it can convert inorganic food into organic compounds with the help of solar energy and with the help of this organic food, animals specially herbivorous animals nourish and the animals either directly take these organic food or they live upon herbivorous animals but whatever be the food, it is ultimately the animals that have to depend upon plants directly or indirectly. As an example, man might take fruits, plants etc., or he may live upon meat but the meat comes from such animals as goat, sheep etc., which can take only small herbs and grass *i.e.,* plants, so the ultimate traceable food is plant-food. The main differences are :—

(1) Plants can manufacture organic food with the help of chlorophyll stored either in soft parts as stems but specially in green leaves whereas animals have no chlorophyll and are entirely dependent upon plants. Plants are therefore called *holophytic* and animals are called *holozoic.*

(2) Plant cells are generally provided with distinct *cell-walls* composed of *cellulose* or in fungi, of fungus cellulose. The cellulose wall is absent from animal cells. In plants, naked cells are exceptionally found as in reproductive stages.

(3) Centrosome is generally found in animal cells but in plant cells with rare exceptions, it is absent.

(4) Respiration occurs both in plants and animals. The protoplasm undergoes oxidation with the liberation of co_2 and energy in both. In the lowest plants and animals, this interchange of gases occurs throughout the entire body surface. In higher plants, interchange of respiratory gases takes place through minute apertures called stomata ; in higher animals, the principal respiratory organs are the gills or lungs found respectively in aquatic and terrestrial forms.

(5) Plants take in simple inorganic substances from the soil in solution with water through the root-hairs for manufacturing organic food in the leaves but animals take prepared organic food through an aperture, the mouth and then inside a digestive cavity. Fungi serve as exception among plants for they live upon organic food.

(6) Plants have no special system to drive away waste products from the body. Animals have a definite excretory system ; the principal excretory organs in higher forms being the kidneys and skin. There is an apology for such a system in the plants, as often excretory products are eliminated with the fall of Bark or outer rind of plants.

(7) Plants and animals both show movements but the movement of the former is less and ordinarily, the movement of the root in the soil is the highest movement but in the special adaptation of winged seeds, the plants conquer the material difficulties in their movement by travelling miles and miles. The animals are without any

restriction in their movements. With a few exceptions, most plants are sessile whereas most animals are motile.

Although the higher animals and plants show well-marked differences, the unicellular animals or the unicellular plant seems to merge with one another in their lowest ranks and a special name is coined for them *e.g.*, the *Protista.*

Summary of difference between animals and plants.

Animals :	Plants :
1. Animals depend on plant either directly or indirectly for their food, in that sense the animal's body is a less equipped chemical laboratory than the body of a plant.	1. Plants can utilise simple inorganic substances from which they elaborate complex organic substances which are used as food.
2. Chlorophyll absent except when acquired from another plant.	2. Chlorophyll present.
3. In animals there is almost a limiting cell membrane which is often protoplasmic and rarely made of cellulose.	3. Cellulose cell wall present except in fungi.
4. Centrosome or attraction sphere is present.	4. Centrosome is rarely present.
5. Respiration in higher forms through gills or lungs.	5. Respiration in higher forms through stomata.
6. Definite excretory organs in the form of nephridia or kidneys in higher animals.	6. No definite excretory organ.
7. Most animals are motile excepting a few such as the sponges, sea anemones, corals and ascidians etc.	7. Most plants are sessile excepting a few aquatic forms such as Chlamydomonas, protococcus, desmids etc.

CHAPTER II

THE PHYSICAL AND CHEMICAL NATURE OF PROTOPLASM

Protoplasm—

Huxley defined protoplasm as the physical basis of life. Without protoplasm there cannot be any life. The protoplasm is a highly complex substance and is not possible to be analysed in the living state. The protoplasm that is studied by biologists is dead because as soon as it is treated with stains and reagents, it loses its living properties.

Properties of protoplasm—

A. **Physical**—protoplasm is a jelly-like substance. It is readily coagulated *i.e.,* it becomes solid just like the hardening of egg-albumen when boiled. It has the capacity to absorb substances of lower concentration *i.e.* it shows the phenomenon of osmosis.

The miscroscopical appearance has been described as :—

(1) **Reticular,** (2) **Fibrillar,** (3) **Alveolar** and (4) **Granular.**

Reticular—protoplasm has been described to be in the form of net work or reticulum.

Fibrillar—protoplasm has been said to be in the form of threads called fibrils connected by other threads.

Alveolar—when there are empty spaces in the protoplasm known as alveolus.

Granular—it states that protoplasm is in the form of minute granules.

B. Chemical—protoplasm is chemically regarded as very rich in proteins. Proteins are always associated with organic life. As the commonest example of proteinaceous substance, egg, fish, meat may be cited. The analysis of dead protoplasm has shown that it is composed of a variety of proteins. They have within them the following elements *e.g.* H, O, N, C, S and some inorganic salts of sodium, calcium, potassium, iron, chlorine and phosphorus.

C. Physiological—protoplasm is responsible for all the life—processes in the organism. Protoplasm carries out the following functions :—

(1) **Nutrition,** (2) **Reproduction,** (3) **Respiration,** (4) **Excretion** etc.

Nutrition—means the taking in of food or food-material and by a series of processes capable of converting them into the life-substance, the protoplasm.

Reproduction—every organism will ultimately die and in order that the kind may not be exterminated from the face of the earth, representatives must be left in the world which in turn will repeat the process by separating a part of the body and thus the series will go on and live in the world. This process is called Reproduction.

Respiration—this process always takes place and essentially consists in the interchange of oxygen of the atmosphere with the CO_2 (carbon dioxide) formed in the body as a result of some vital activity within the body.

Excretion—this process means the discharge of waste-products from the body. In the plant, the system of excretory organs is not so well developed as in the animal kingdom, which carry on this process.

Protoplasmic movement—

Protoplasm is always in a state of movement. The movement of protoplasm :—

(1) **Rotation**—when the movement is in a definite direction *e.g.*, Vallisneria.

(2) **Circulation**—when the movements are in several directions *e.g.* in the hairs on the stamens of Tradescantia.

(3) **Amœboid**—when the movement takes place by the throwing out of blunt processes called Pseudopodia *e.g.* Amœba.

(4) **Ciliary**—when the movement takes place with the help of fine hair-like processes called Cilia *e.g.* Spermatozoids of Fern and Moss.

Tests for protoplasm—

(1) It coagulates with the application of heat and alcohol.

(2) It turns yellowish-brown when treated with iodine.

(3) It turns yellow with Nitric Acid and the yellow colour becomes deeper with the addition of ammonia.

Average percentage composition of protoplasm.

Carbon	50 to 55 %
Hydrogen	6·5 to 7·3 %
Nitrogen	15 to 17·6 %
Oxygen	19 to 24 %
Sulphur	·3 to 2·4 %

Protoplasm is regarded to be in the colloidal state. Colloidal substance consists of ultra-microscopic particles suspended in a medium of fluid or semifluid consistency. The particles form the disperse phase and the solute, the continuous phase. All such structure is invisible to the naked eye, being of ultra-microscopic size, but always within the protoplasm small microscopic granules or drops are visible and these do not form part of the essential permanent protoplasmic structure but are small aggregations of fats, carbohydrates or proteins which have been temporarily formed as a result of the protoplasmic activity. They may be referred to as "*metabolites*." Such a substance may be an **Emulsion.**

The protein part of protoplasmic colloid is readily and irreversibly coagulated by high temperatures and with this coagulation, the life of the cell comes to an end.

Within fairly wide limits, the protoplasm can lose or gain water in the manner of gelatine, passing from one condition to the other readily and reversibly according to conditions.

A colloid which looks like a solution is called a *sol*, and that which is semi-solid in consistency is known as *Gel*. *Cytoplasm* is an example of Sol, while the *nucleus* is Gel.

Above 40°C, the structure of the protein molecules is affected and the irreversible coagulation changes set in. Thus the protoplasm can be said to exist normally in a state intermediate between that of a sol and a gel and a change in either direction is very readily caused by temperature, changed water-content, changed salt concentrations and by different hydrogen-ion concentrations.

If protoplasm is subjected to a solution of salt or sugar, it will allow the water to pass but not the substances with larger molecules. Thus protoplasm is said to be *semipermeable*.

The nuclear composition has an additional element namely *phosphorus.* The different kinds of proteins which are abundantly found in it are nucleo-albumin, globulin and peptones.

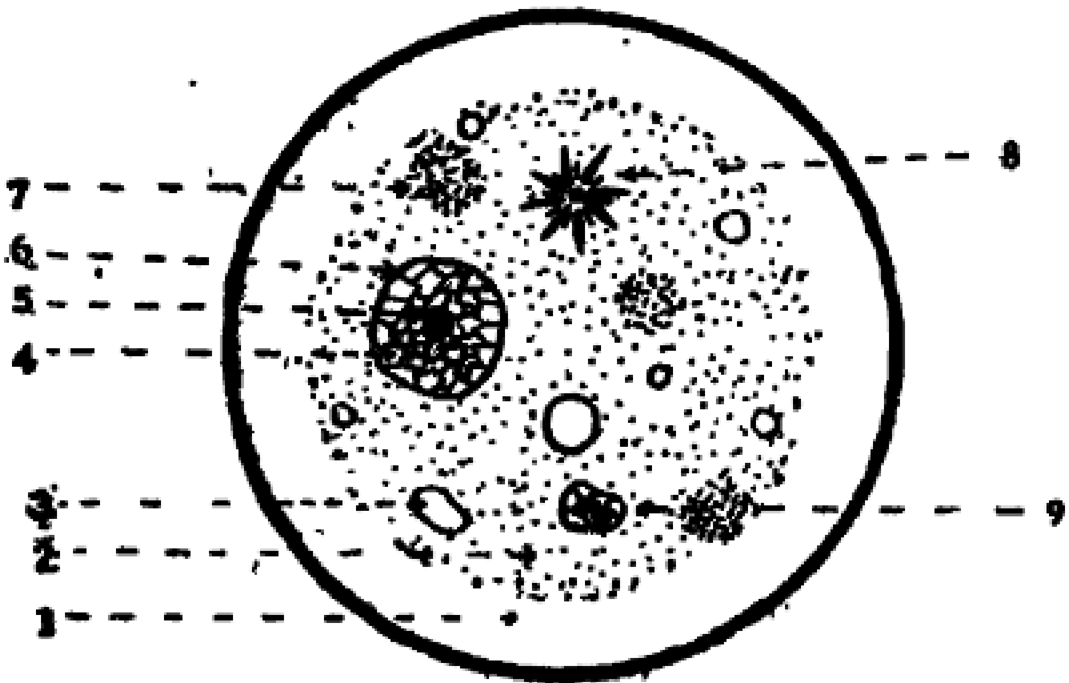
Cells—

Cells are the structural and functional units of the animal body. In the case of a unicellular animal, the single cell has to carry out all the functions but in a multicellular animal, several cells combine to form a tissue and tissues are in their turn specialised to perform definite functions of the body. The **animal cell** is peculiar in this respect that the definite **cel-wall** is absent. It consists of a spec of protoplasm differentiated into (*a*) **Cell-membrane,** (*b*) **Cytoplasm** and (*c*) **Nucleus.**

Cell-membrane—This is the limiting membrane of the cell and occurs in the form of a thin pellicle. In most animal-cell this is a specialised part of the protoplasm and hence a living structure.

Cytoplasm—The portion of the protoplasm within the cell-membrane and surrounding the nucleus is known as cytoplasm. The cytoplasm consists of an outer transparent **Ectoplasm** and an inner granular **Endoplasm.** Embedded in the cytoplasm and lying close to the nucleus is a star-shaped body known as **Centrosphere.** Within which are one or two granules called **Centrosomes.** The centrosphere plays a very important part during cell-division. The cytoplasm also contains **Mitochondria** in the form of rods and cones and **Golgi-bodies** which can only be demonstrated by treatment with special stains and reagents.

Cavities or gaps are often met with in the cytoplasm. These contain a fluid called cell-sap and are known as **Vacuoles.**



Animal cell.

1. Ectoplasm.
2. Endoplasm.
3. Vacuole.
4. Nuclear reticulum.
5. Nucleolus.
7. Mitochondria.
6. Nuclear membrane.
8. Centrosphere.
9. Golgi body.

Nucleus—It is the most dense part of the cell-protoplasm and is bounded by the **Nuclear-membrane** within which lie the **Nucleoplasm.** The latter is made up of a network of **linin-threads** containing thick corners of **Chromatin granules.** Within the meshwork there is a fluid called **Nuclear-sap** or **Karyolymph.** Here and there chromatin granules are aggregated to form bodies called **Nucleoli.**

Cell division—

The growth of an animal or plant results from the division of its cells. There are some unicellular animals which also must divide to give rise to new animals. There are several methods of cell division. Some are very simple, others are complicated in their process of division.

The principal types are :—

(*a*) **Direct division,** (*b*) **Indirect division** or **Mitosis** or **Karyokinesis,** (*c*) **Reduction division** or **Meiosis,** (*d*) **Free cell formation.**

Direct division—

Direct division occurs in the lowest group of animals namely the *protozoa.* The nucleus first elongates and assumes the form of a dumb-bell and the cytoplasm also constricts and separates into two cells, *e.g.,* Transverse division of Paramoecium specially the meganucleus, Amoeba.

Indirect division or Karyokinesis or Mitosis—

(*After Dr. Hans Grüneberg, Ph.D., M.D.*)

Nuclear division of the sort almost universally found in plants and animals is called Mitosis. The resting nucleus of a cell is a vesicle of varying shape surrounded by a nuclear membrane. It consists of fine threads in a tightly coiled bundle. The threads are the **Chromosomes** and to one or two of them, a darkly staining body, the nucleolus may be attached. Chromosomes can be distinguished from other constituents of the cell by a specific chemical test (Feulgen) and are stainable with basic dye-stuffs such as haematoxylin and gentian-violet.

The stages of mitosis which can be followed in living cells or fixed preparations, are :—

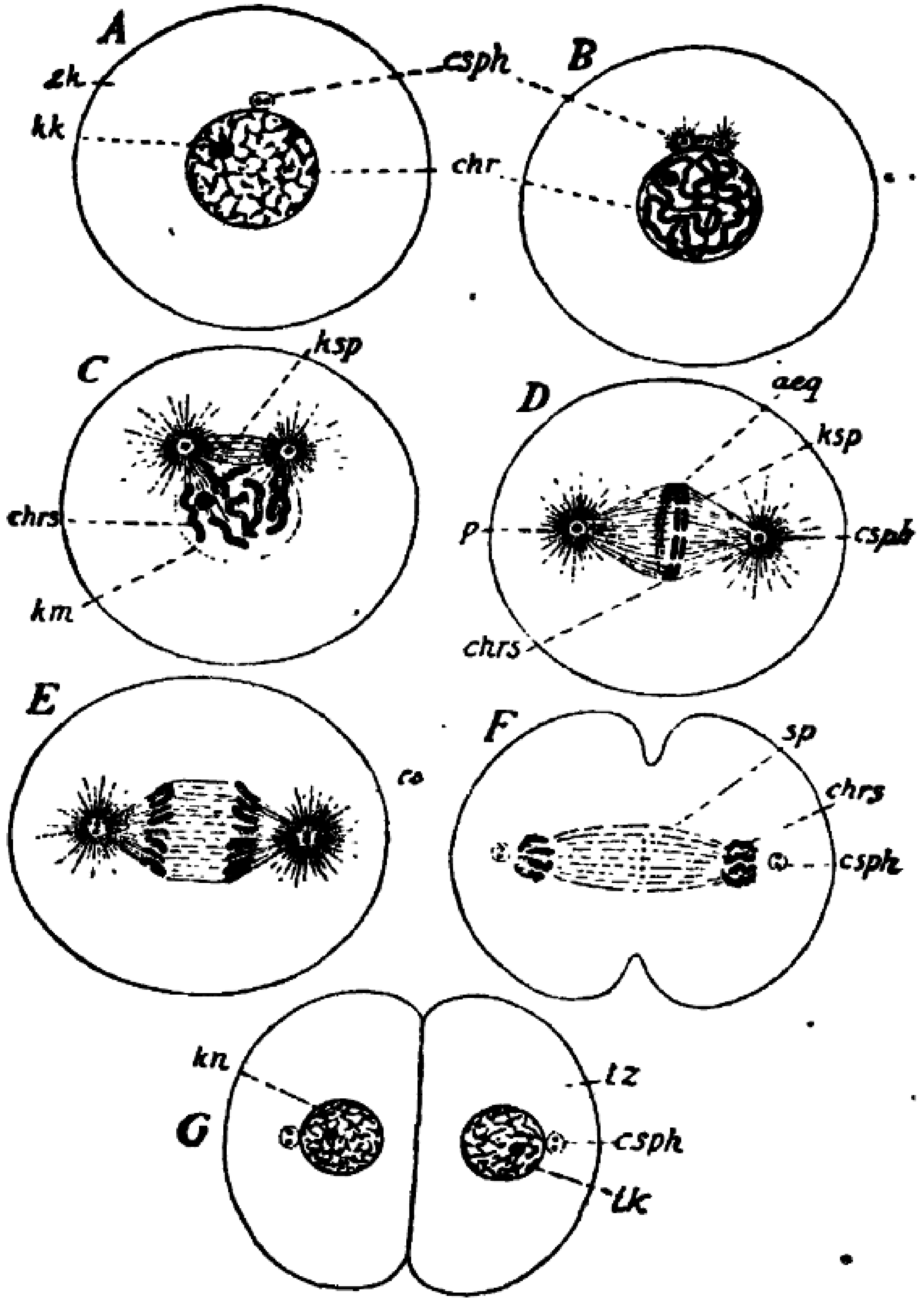
(1) **Prophase**—Separate chromosomes become visible as fine long threads. They consist of little granules called **Chromomeres,** connected by a fine thread like beads on

string. Each chromosome is a double thread, a longitudinal split having occurred prior to prophase in the resting nucleus. Each half is called a **Chromatid** but the two daughter-chromatids of each chromosome are still connected at one point. At later stages of Prophase, the chromosomes contract by forming a close spiral thereby getting thicker and shorter and staining darker in preparations.

(2) **Pro-metaphase**—The nuclear membrane becomes dissolved at the end of prophase so that the chromosomes are lying free in the cytoplasm of the cell. A spindle of denser cytoplasm is being formed, parts of which are contributed by the nuclear sap. The poles of the spindle which in some organisms emanate from a darkly staining body, the centriole or centrosome, are at opposite sides of the nucleus. The chromosomes have contracted lengthwise considerably. That part of each chromosome which was not yet divided at prophase attaches itself to the spindle; it is called the spindle attachment or Centromere. Now this Centromere also divides.

(3) **Metaphase**—The chromosomes arrange themselves in the equatorial plane of the spindle to make a flat circular "plate."

(4) **Anaphase**—The two daughter chromatids of each chromosome move towards opposite poles of the spindle. This disjunction starts at the Centromere which therefore is responsible for the separation of the chromatids. Since the two groups resulting from this separation each receives a daughter chromatid of every chromosome, two complete and exactly corresponding sets of chromosomes are formed.



Karyokinesis or Somatic type of nuclear division.

A. Resting cell,
B. Centrosphere dividing into two, prophase.
C. Nuclear Spindle formed
D. Metaphase,
E. Anaphase,
F. Telophase.
G. Daughter cells.

Zk. Cytoplasm,
Csph. Centrosphere,
Kk. Nucleolus,
Chr. Chromatin,
Ksp. Spindle,
Chrs. Chromosomes,
Km. Nuclear membrane.
Cs. Centrosome.
Tz. Daughter cell.

(5) **Telophase**—New nuclear membranes are formed round the two new nuclei. New nucleoli are formed, replacing the one dissolved during mitosis in each daughter-cell, and a division of the cytoplasm between the nuclei marks the end of mitotic cell division.

The number of Chromosomes is constant in a given species—

Each animal or plant species has in all its body cells a constant number of chromosomes visible at every somatic cell division. In a few groups, the two sexes differ as to chromosome number.

Species	Number of Chromosomes.
Entamoeba histolytica	6
Culex pipiens (mosquito)	6
Anopheles	6
Drosophila melanogaster (fruit fly)	8
Musca domestica (house fly)	12
Lucilia (green-bottle)	12
Calliphora (blue-bottle)	12
Pisum sativum (garden pea)	14
Zea mays (maize)	20
Rana temporaria (frog)	26
Mus musculus (house mouse)	40
Man	48
Bombyx mori (silk-worm)	56
Rumex hydrolapathum (great water dock)	200
Cambarus sp. (crayfish)	208

The chromosome number is usually even, suggesting that the chromosomes are present in pairs. Some exceptions to this rule do occur.

The shape of the Metaphase Chromosomes—

The shape of the chromosomes at metaphase may be rod-like, or V-shaped with two equal arms, or L-shaped with a long and short arm, or very short ovoid or globular. Often a chromosome has a little knob attached to one end called a **Trabant or Satellite.** In the chromosome complement of any given species, several types of chromosomes may be present simultaneously. So in Drosophila melanogaster (fruit fly) four out of eight chromosomes, are always V-shaped, and two others are always dot-like and very small. So not only the number of chromosomes, but also their shape is characteristic for each species. **Each chromosome has an individuality,** and in many species with not too numerous chromosomes and sufficient differences in chromosome shape and size, individual chromosomes are easily identifiable at every cell-division.

In such cases it is seen that **chromosomes are present in pairs, the partners of which correspond to each other.** So in Drosophila melanagaster females, there is one pair of rod-like chromosomes, two pairs of V-shaped chromosomes and one pair of very small globular chromosomes. The members of such pairs which are usually (with one important exception) of very similar shape and size, are called **Homologous chromosomes.** The homology of chromosomes in pairs becomes very obvious at the maturation divisions preceding the formation of sex-cells, even when that homology is not so striking in somatic divisions.

MEIOSIS

The two nuclear divisions preceding the formation of functioning sex-cells are called the **first and second meiotic divisions,** the whole process is called **Meiosis.** In animals the process leading to the formation of male gametes or spermatozoa is called **Spermatogenesis** and that leading to female gametes is called **oogenesis.** In plants the corresponding terms are **Micro and Megasporogenesis.**

Spermatogenesis—

The prophase of the first meiotic division is characterised by a number of complicated processes not found in any other cell division. The following stages are distinguished:—

(1) **Leptotene**—The chromosomes appear as fine coiled threads within the nucleus. Their number is, of course, that characteristic of the species.

(2) **Zygotene—Homologous Chromosomes** start pairing in such a way that the two threads lie parallel to each other. This intimate pairing brings corresponding parts of the chromosomes side by side. Thus at this stage, the number of chromosome pairs or **Bivalents** is just half the number of single chromosomes of the set seen at mitosis.

(3) **Pachytene**—The chromosomes get somewhat thicker and it becomes obvious that each of the paired chromosomes (A and a) has divided longitudinally into two daughter chromatids, so that the whole group now consists of four threads (A′ A″ a′ a″). Each homologue is represented by two identical daughter chromatids, which, however, are still connected at the spindle attachment.

(4) **Diplotene**—As soon as the splitting of chromosomes into two daughter chromatids has taken place at pachytene, the attractive force which brought homologous chromosomes parallel to each other ceases to exist. Homologues open out again and would separate completely, if they were not held together at one or several points by what are called **chiasmata.** A **chiasma** is a crosswise connection between two chromatids of a bivalent which are not the daughter strands of one original chromosome. So either of the two A strands may form a chiasma with either of the "a" strands. At any given level of the bivatent only two of the four strands are involved in a chiasma; but if several chiasmata are formed, other strands than those forming the first one may contribute to the second or third chiasma.

After the formation of chiasmata has taken place, chromosomes contract, getting shorter, but much thicker. This contraction reaches a maximum at metaphase when the bivalents have arranged themselves in an equatorial plane.

At the anaphase of the first meiotic division the bivalents separate in such a way that at the spindle attachment which initiates disjunction, the two daughter chromatids of each homologue remain together since the spindle attachment point, unlike the rest of the chromosome, has not undergone division at pachytene. So A′ and A″ go into one cell, while a′ and a″ pass into the other. It is to be clearly understood that this applies only to the region of the spindle attachment. The failure of the spindle attachment to divide is peculiar to the first meiotic division and does not occur at any other cell division. The concluding phase of the first meiotic division is usually at once followed by the beginning of the second meiotic division. Each of the two nuclei resulting from the first division divides again. No new division of chromosomes takes place at this division, but the two chromatids left together at the previous division now pass to opposite poles of the spindle. So altogether four cells are being formed which now differentiate into mature spermatozoa.

Result of the two Meiotic divisions—

There are two cell-divisions, but during these divisions the two homologues of a pair, A and a, have divided only once (at pachytene of the first division) forming the bivalent A′ A″ a′ a″. The four strands of the bivalent are now distributed to four cells. Each of the resulting cells, therefore, receives only one of the chromatids, either A′ or A″ or a′ or a″. Since this applies to all the bivalents, the net result is the formation of cells which do not contain the full set of chromosomes, but only half that number. They, therefore, carry only one member of each pair of homologues

The result of meiosis is therefore reduction of chromosome number. If the somatic number of chromosomes is $2n$, each spermatozoon contains only n chromosomes. We call the somatic number ($2n$) **diploid,** while the gametic chromosome number (n) is called **Haploid.** Drosophila, for instance, has Diploid 8, haploid 4 chromosomes, man respectively 48 and 24. This halving of the chromosome number is called **Reduction.**

Free cell formation—

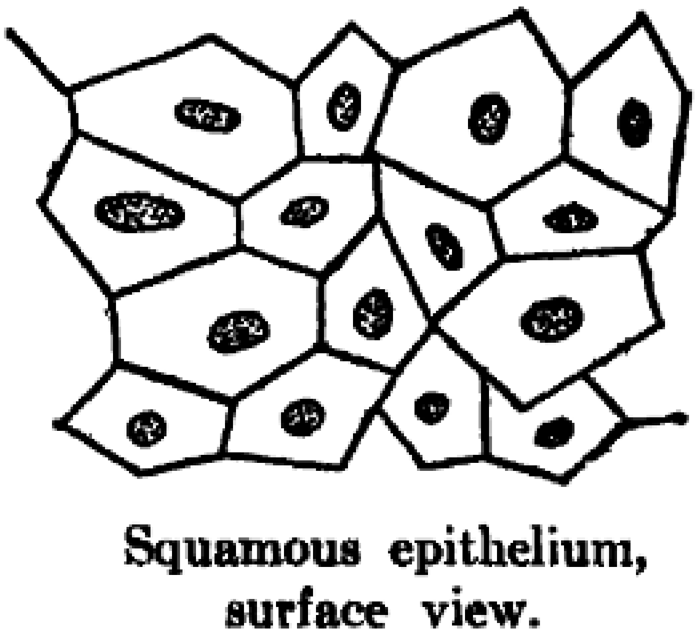
Sometimes the nucleus is divided into a number of parts and later on cytoplasm collects to each bit of nucleus to form a number of naked cells. This is known as free cell formation *e.g.* gametes of Monocystis.

Tissue and Tissue-system in animals—

Tissue means a collection of similar cells performing a definite function in the body. There are various tissues in the body of an animal. These tissues combine to form **organs.** Example of organ is the eye, tongue, liver etc. Practically organs also combine to carry out different functions of the body, such a combination of organs is known as a **system.** Thus urine is manufactured inside the kidney, from the kidney it passes by a passage called ureter and collects inside a sac called urinary bladder, now the whole work is accomplished through these organs namely kidney, ureter and bladder and they form a system called **urinary system.**

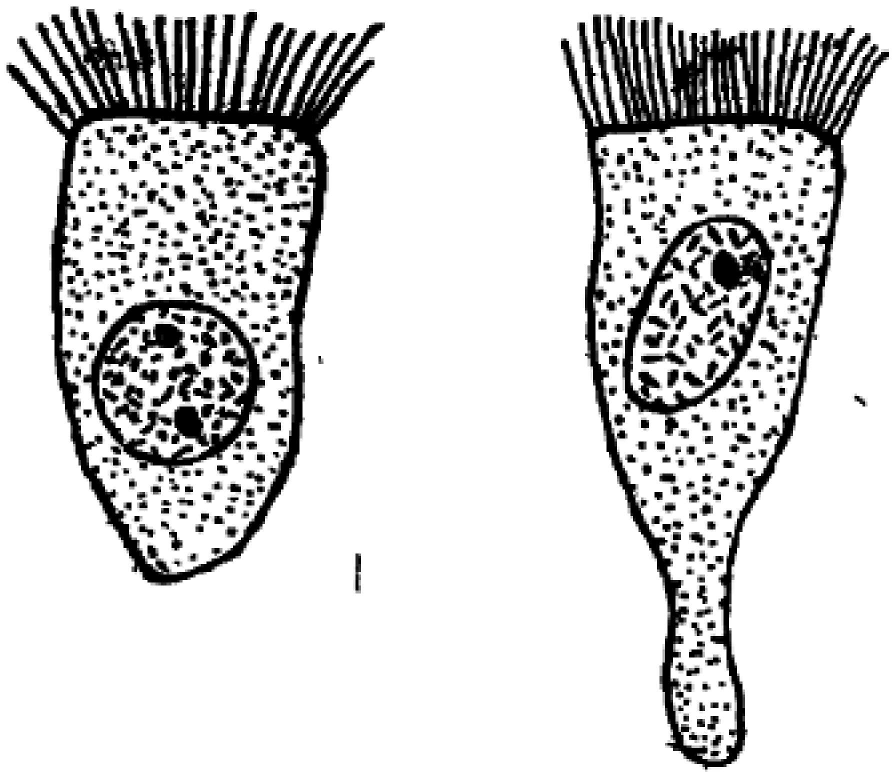
There are four kinds of *tissues*:—(*a*) **Epithelial,** (*b*) **Muscular,** (*c*) ***Connective*** and (*d*) **Nervous.**

Epithelium means a boundary and epithelial tissues are found to cover the external and internal surfaces of the animal. There may be **simple epithelium** consisting of a single layer of cells or **compound epithelium** consisting of two or more layers of cells. According to the shape of the cell, the epithelial tissues are of the following kinds :—



Squamous epithelium,
surface view.

(*a*) **Columnar**—In this the cells are tall, lying side by side like columns. Between the cells, there are fine crevices which communicate with lymph-spaces; found in the lining of the intestine of Toad.



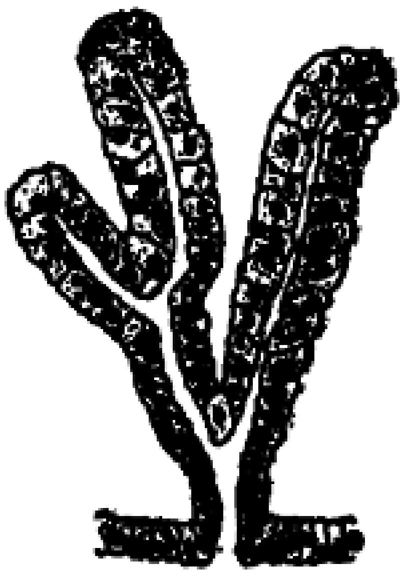
Cilated epithelium from toad's mouth. Cell with cilia.

(b) **Ciliated,** this is a modification of columnar epithelium and has a lining of fine protoplasmic hairs on the outer borders of the cells. The hairs are called **cilia** and are in constant motion in one direction found in the roof of the mouth of Toad.

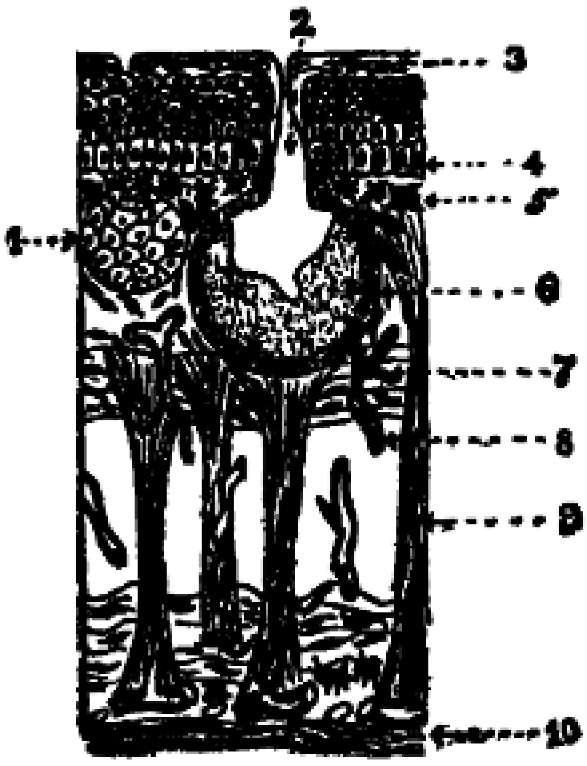
(c) **Glandular epithelium** is a kind of epithelium, in which the cells become specialised for the secretion of chemical substances. The glands might be simple or compound. This is found in the stomach of Toad.

(*d*) **Squamous** epithelium is a kind of simple epithelium. The surface of this tissue seems to be composed of flat tiles like a pavement found in the lining of blood-vessels, coelome, toad's skin.

(*e*) **Stratified** or **compound epithelium**—In this several layers of cells are found. The innermost layer is generally soft and is known as **Malpighian layer.** The outer layers become more and more flat and horny, as in the skin or epidermis of toad. The outer cells fall off and are renewed by new cells from the soft layer.



Glandular epithelium from the alimentary canal of Toad-stomach.



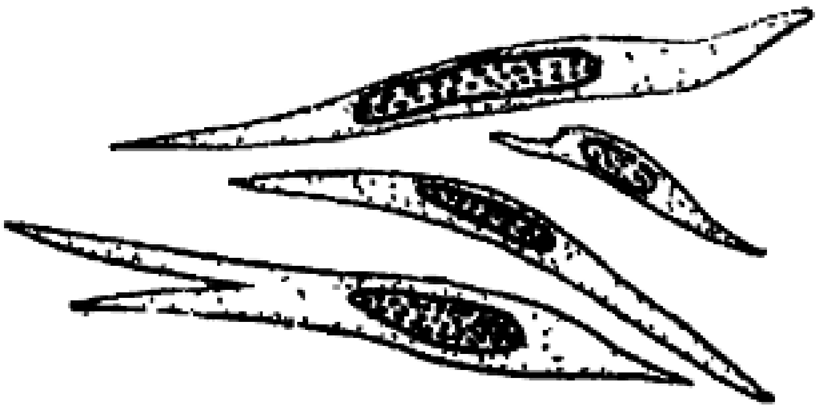
Stratified epithelium from toad's skin. (*Section*)
1. Cutaneous gland. 2. Duct. 3. Epithelial cells. 4. Malpighian layer. 5. Pigment cells. 6. Gland. 7. Connective tissue. 8. Blood-vessel. 9. Connective tissue. 10. Connective tis-

(*f*) **Cubical epithelium**—This consists of cubical cells. They are found in the gonads where they give rise to germ cells.

Muscular tissue—

The movements of the body are generally controlled by the contraction of this tissue. This tissue consists of elongated cells which are highly elastic and contractile. Muscle fibres are of two kinds, (*a*) **Striated or Striped** and (*b*) **Plain or unstriped or unstriated.**

Some of the muscles are under the control of the will *i.e.* the animal can control the movement which is generally called **voluntary** type and is striated. Others are not under the control of the will and are called **involuntary.** They are generally unstriated. Exception —heart muscle though striated is involuntary. The fibres of plain muscle have elongated cells with nuclei in the middle *i.e.* each cell has a single nucleus *e.g.* muscular lining of intestine.



Unstriped muscle fibres with nuclei.

Striped muscle fibre dark and light bands from toad's leg.

The fibres of the striped variety are cœnocytes *i.e.* each fibre contains several nuclei and their cytoplasm exibit alternate light and dark stripes. The nuclei are scattered along the length of the fibre. The fibres are surrounded by a sheath called **sarcolemma** which adheres to the adjacent fibre or tendon as in the leg muscles of Toad.

Heart muscle—

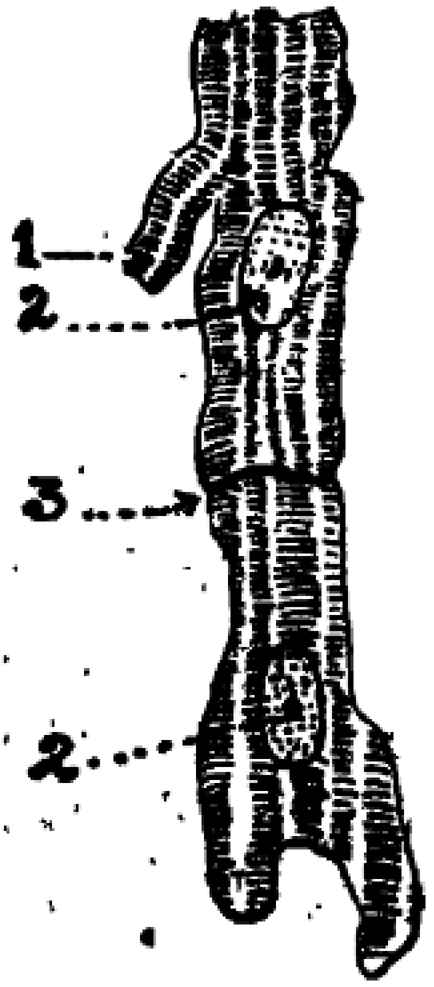
The heart muscle although of the striped variety is an exception. Each cell has a nucleus and is striped but it is not under the control of the will; the automatism lies within its own tissue which has slightly less distinct striations than ordinary muscle.

Connective tissue—

This tissue develops plenty of intercellular substance to bind together or support other tissues. The connective tissues may be of the following types :—(1) **Connective tissue proper,** (2) **Cartilage,** (3) **Bone** and (4) **Blood.**

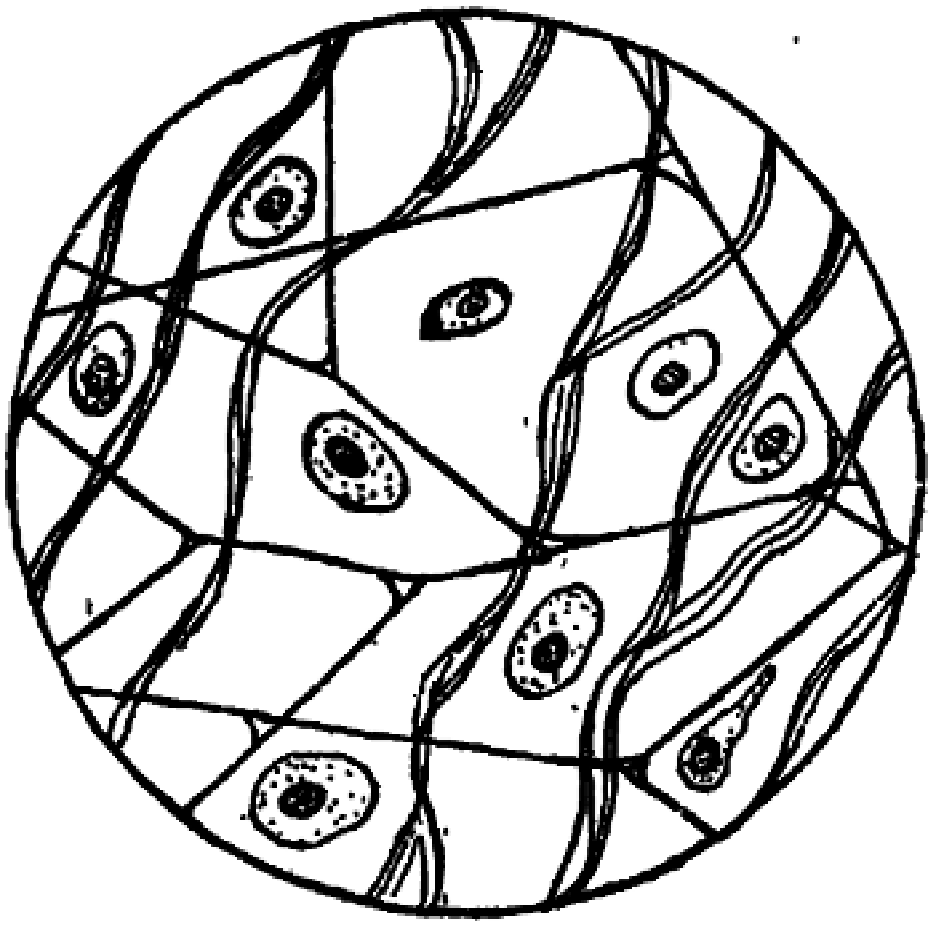
(1) **Connective tissue proper**—As the name indicates it connects other tissues. They contain fibres of two kinds *e.g.* **white fibres** which may branch and have a wavy course but never join with one another and are composed of fine fibrils. The yellow fibres or elastic fibres join up to form a network but are not composed of fibrils.

Heart muscle of Toad.



1. Fibre-branch.
2. Nucleus.
3. Partition.

Connective tissue.

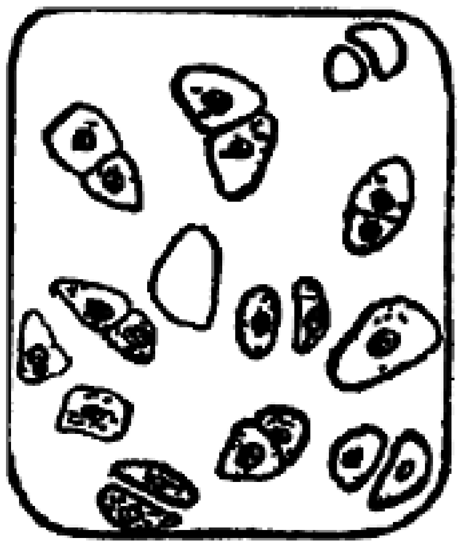


Cells, yellow fibres—run singly, white fibres—in bundles.

When connective tissue is boiled, the ground substance gives **gelatin.** In the ground substance of connective tissue, spaces are found which are occupied by scattered connective tissue **corpuscles.** Connective tissue almost penetrates every part of the body holding the softer tissues in position; under the skin it forms a continuous layer called **dermis.** The dermis is covered by epithelial layer called **epidermis.** **Tendon** is a modification of connective tissue and serves to connect muscles to bones.

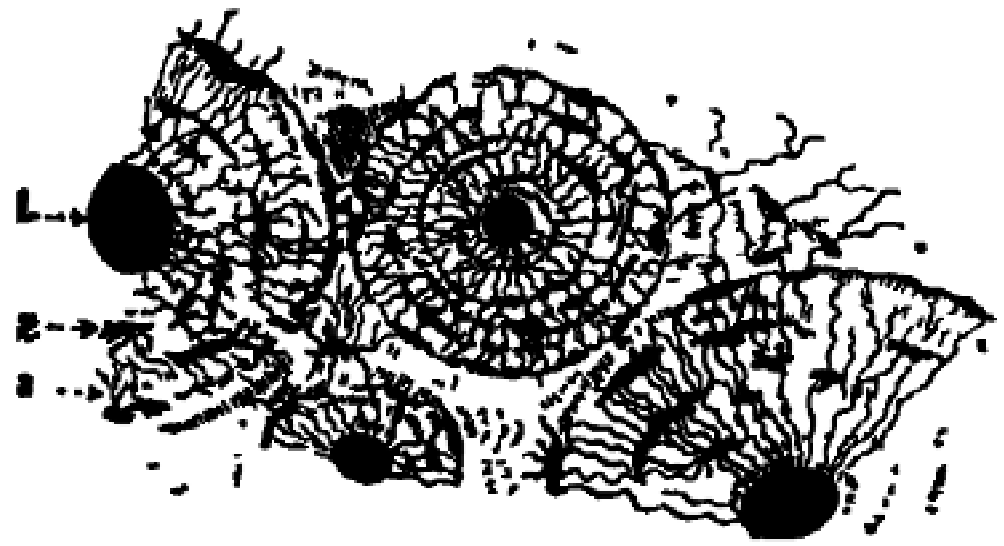
Cartilage is found in the pinna of external ear. It has a homogeneous ground substance. The cells are found in pairs in the ground substance which separate due to the secretion of the cells. There are two kinds of cartilage. One kind shows abundant development of fibres and is known as **fibrous cartilage.** The other kind does not show any fibre but has a hyaline ground substance and is called **hyaline cartilage.**

Cartilage.



Ground substance, cells are dividing.

Section of decalcified bone

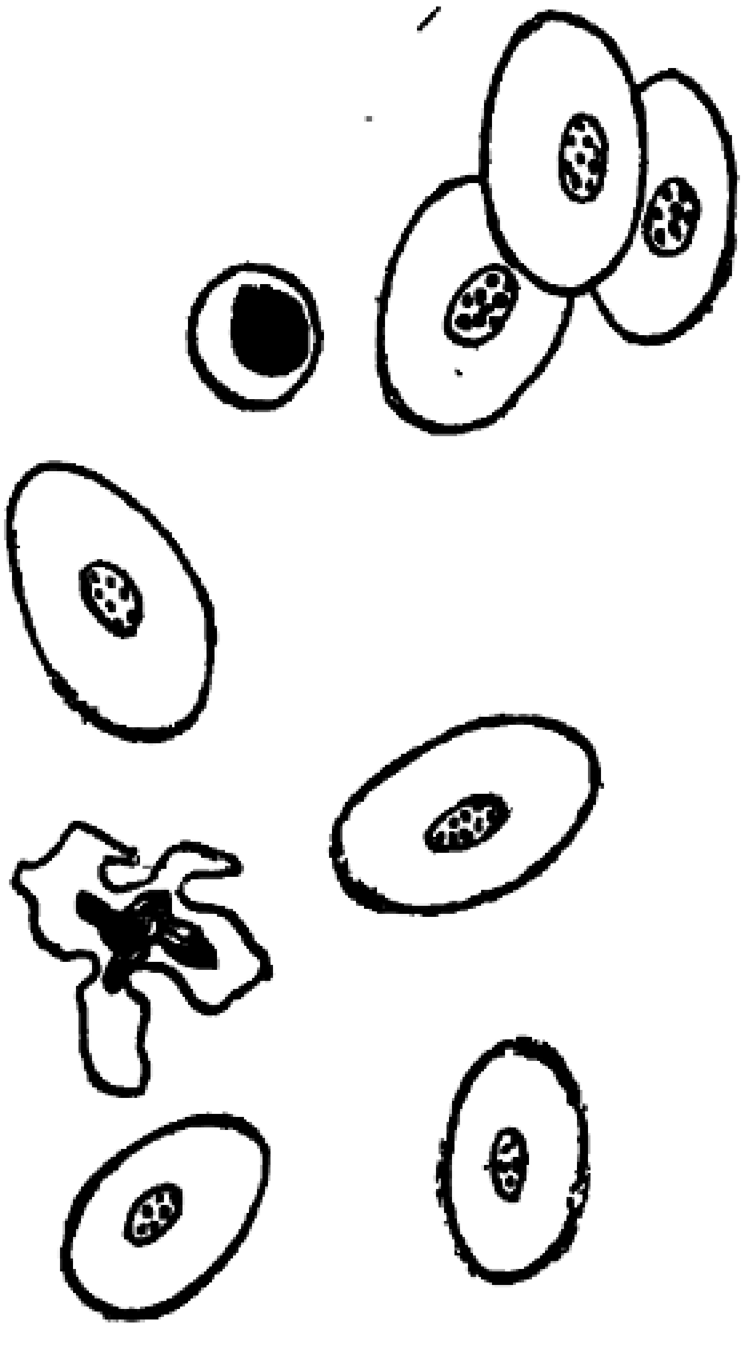


1. Haversian canal. 2. Bone-cell. 3. Lamellae.

Bone—

The ground substance of this tissue consists of animal matter on which calcium phosphate or carbonate is deposited. A thin section of frog's bone shows that it is composed of many thin layers or **lamellæ** surrounding the **marrow cavity.** In the lamellæ are found numerous cavities called **lacunæ** with delicate branching tubes called **canaliculi** which run in all directions. The cavities in sections appear black owing to the presence of air in them. The lacunæ contain the *bone cells.*

Blood is a kind of liquid connective tissue, for it has liquid ground substance. Mainly two kinds of cells are found in blood. They are called **corpuscles** e.g., *white* and *red blood corpuscles*. The white blood corpuscles play a very important part in the body because they can



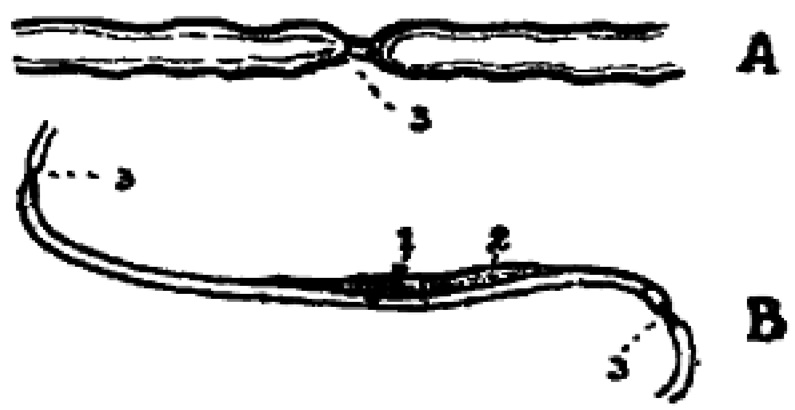
Blood of Toad. Oval—Red blood corpuscle, Round and irregular—white blood corpuscles.

devour disease producing bacteria introduced into the body of the animal. The red blood corpuscles supply nutrition to the tissues and are also carriers of a colouring matter called *Hæmoglobin* which play an important role in respiration. The liquid ground substance of the blood is called **Plasma.** Blood when shed, sets into a jelly-like substance, this is called **clotting** or **coagulation** of blood.

Nervous tissue—

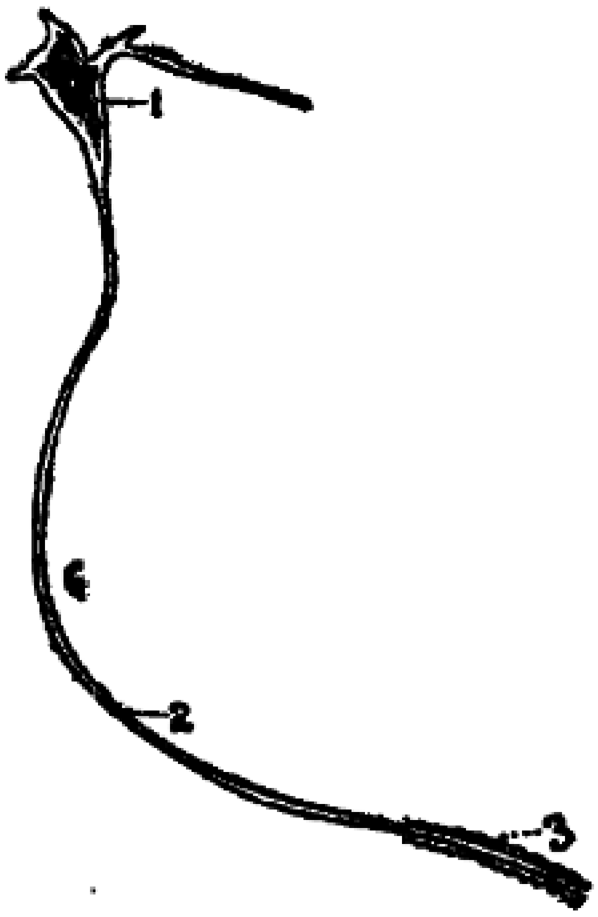
The body of the animal is traversed by fine thread-like structures called **Nerves.** These nerves carry messages of the body. The nerves give us the power to discriminate the hot from the cold substance and various other sensory intelligence. Suppose a substance is hot, the feeling of hotness is carried by nerves to the brain and immediately another set of nerves coming from the brain order the part of our body to remove from the hot substance. Therefore a central station is seen *e.g.*, the **brain** which is called the **central nervous system** and there are two sets of nerves, one is **efferent** and the second is **afferent.** The sensation is carried from the outside to the brain by *afferent* or *sensory nerve* while

Nerve fibres.



1. Nucleus of sheath. 2. Neurolemma.
3. Node of Ranvier.

the reverse order, that is, from the brain to the tissues is by *efferent* or *motor nerve*. The nervous tissue is composed of cells or **neurons.** Each cell has a cell-body containing the **nucleus,** a long process called the **Axon** and a branching end called the **Dendron** or **dendrite.**



Nerve cell.

1. Nucleus. 2. Axon. 3. Process of medullary sheath.

The **axon** often is very long and takes the form of a **fibre.** The nervous tissue run in bundles enclosed by a sheath of connective tissue. While examining a nerve, this sheath must be torn off with needles to expose the nerve fibres.

Each nerve fibre has a central axis called **Neuraxis** or **axisfibre.** Around this, is a *sheath* called *medullary sheath* and finally covering the whole is a membrane called **neurolemma.** At intervals, nodes are produced due to the absence of medullary sheath called **Nodes of Ranvier.**

A collection of nervous tissue is known as *Ganglion* where nerve fibres and nerve cells are found.

The ***brain*** and ***spinal cord*** **form** the central nervous system while the nerves both efferent and afferent form the *peripheral system.*

In the autonomic-nervous system, the nerve fibres are devoid of any medullary sheath. These fibres constitute the non-medullated nerve fibres as distinguished from the medullated fibres just described.

CHAPTER III

NUTRITION AND GROWTH

The living organism takes in food or food-material for its nourishment, that process is called nutrition. The animals take their prepared food either from plants or from animals. The plants, however, have to take their food material in the form of solution through root-hairs except in the case of Fungi or in the case of insectivorous plants which live upon organic life.

The simplest animal like the Protozoa and specially the amoeba, gets hold of food through pseudopodia or false feet and then transfer them to the food vacuole for digestion. The next higher animal namely the Hydra gets hold of the food through tentacles and transfers them to the coelenteron for digestion. In the third higher group in complexity of structure namely the Leech, the food is sucked and then transferred into the alimentary canal for digestion. The freshwater prawn, the fourth higher group and almost the highest among Invertebrata, nutrition is in the form of engulfing food with the help of appendages and legs.

The vertebrata or the back-boned animals generally live upon organic food but that food must be digested with the help of certain secretions from glands like liver, pancreas etc., which make them fit to be absorbed into the blood stream to supply nourishment to the tissues of the body.

The lowest plants simply absorb water through their body and generally with the help of sunlight and chlorophyll can manufacture their food.

The fundamental difference in nutrition in the two kingdoms of animals and plants lies in the fact that the former is only capable of taking organic food whereas the latter takes in inorganic food-material. The nutrition of animals is holozoic whereas plants have holophytic mode of nourishment.

When the food has been digested, it enters into the body and supplies every living cell. In the higher animals, the nutritive material enters the blood stream and supplies different organs and tissues of the body. If there is extra amount of food after compensating the loss which always occurs in the body for the production of energy, growth takes place. Growth always occurs whenever there is extra amount of nourishment and the second factor is the healthy condition of cells.

The higher plants also grow when there is additional amount of nourishment after meeting the immediate amounts necessary for the loss undergone by the plant in the production of energy. As a matter of fact, every living cell whether it is a unicellular organism or a multicellular one, has to burn part of the protoplasm for the production of energy. Nutrition is necessary to make good this loss and the additional amount is utilised for its growth. Growth means, in the higher organism, addition of new cells manifested outwardly by increase in size.

The higher animals take the food but that food as it is, cannot be absorbed by the tissues so a detailed process is gone through known as digestion. Digestion takes place by several stages, the first stage takes place with a juice called salivary juice secreted by salivary glands situated in the mouth. The next stage is inside the stomach, where the walls secrete a juice known as Gastric juice and the final digestion is brought about in the small intestine where juices from pancreas and liver make the food fit to be passed into the blood stream. Without entering into details, it will be useful to remember that certain chemical agents known as Enzymes help digestion but they are not themselves used up in the process.

Higher plants also have to digest before the food can be used for the welfare of the plant body.

Circulation of Nutritive Materials—

The nutritive materials enter the plants through root-hairs by a process of osmosis. Osmosis means that the substances of higher concentration always attract substances of lower concentration when separated by permeable membranes. In the case of plants by osmosis, water and dissolved inorganic substances enter the roots and by a second process called root-pressure which is generated in the roots, the water is pumped up the stem through xylem vessels. There are other factors which help the rise of water in the xylem vessels. Therefore, it is seen that the material enters and passes through the xylem vessels and finally reaches the leaves. In the leaves, the manufacture of organic food takes place. When the organic food is prepared, the easily available form is sugar; this sugar immediately passes through another set of tissue called phloem. Therefore in the plants, there is extreme specialisation regarding the path for food-material and food. The phloem carries the food generally in the form of sugar to parts where there is immediate necessity. The extra amount of food is stored up inside the plant for future use in the form of starch.

The lower plants like Spirogyra absorb nutrition through their surface and as they live in water, dissolved substances have easy access to their cells.

The fungi which are either parasitic or saprophytic, absorb nourishment through mycelium. As the fungi can live only upon organic matter, the process of absorption is direct and that serves as food.

The higher animals take the food through the mouth, after a brief process of chewing or mastication when salivary juice mixes with the food, it passes into the stomach. In herbivorous animals, the digestion is delayed in the stomach, because in some animals, the stomach has several chambers. When the animal first takes its food, it passes into the first chamber, then it is again brought to the mouth for chewing when the animal feels leisurely and finally it is passed into the other chamber to be transferred to the intestine. The first part of intestine namely the small intestine not only carries out the remaining process of digestion but the actual absorption into the bloodstream takes place in this part. The residue mainly consisting of waste products pass out through the large intestine to the outside world in the form of faeces. The carnivorous animals have the process of digestion much simplified and it begins in the mouth, continues in the stomach and finally sent into the small intestine where juices come from glands like liver, pancreas and nourishment is sent to the blood. The lower animals like protozoa have nourishment from the surface and with the help of food-vacuole digest them. In Hydra, there is only one aperture through which food enters the coelenteron where digestion takes place. The leech takes nutrition in the form of blood and gradually digest drop by drop which may last for one year *i.e.*, one meal may be digested in one year. The prawn has digestive glands and alimentary tube which may be compared to digestion of higher animals although not so specialised.

Respiration—

Respiration means the interchange of CO_2 (carbon dioxide) for oxygen, in other words, the taking in of oxygen and giving out of carbon dioxide. The animals and plants always undergo some loss in the form of oxidation. The protoplasm is undergoing combustion to produce energy. This process of combustion occurs both in animals and plants. It essentially consists in the use of oxygen by tissues and the resultant production of carbon dioxide which must be eliminated. This process is responsible for the production of energy which gives the power to work.

The higher animals like man, tiger, guineapig etc. respire through special organs, called the lungs. Air enters through the nostrils, passes to the back of the mouth, enters the glottis and thence to larynx and trachea and finally makes its way inside the lungs. The lungs have fine blood-vessels in the form of capillaries which absorb oxygen and eliminate CO_2.. The impure blood with CO_2 is brought to the lungs from the heart and the impure blood after purification again passes into the heart. The result of oxidative processes in the body is the gaseous substance CO_2, which acts as poison to the body, therefore the sooner it is got rid of, the better for the animal. The toad or frog in the adult stage respires through the lungs.

The fish has a peculiar method of respiration. The gills are the organs for respiration, here the current of water brings with it, the dissolved oxygen that is passed through the gills where there are capillaries to absorb it and give out CO_2 from the blood which is circulating inside them.

The simple animals like protozoa, give out CO_2 through their surface. The prawn have gills which eliminate CO_2 to the outgoing current of water.

The plants also respire, CO_2 is given out and oxygen is taken in. In the higher plants, there is no such organ as the lungs but there are minute apertures on the leaves called stomata which perform the function of respiratory organ. Ordinarily, oxygen is taken in from the air and CO_2 is given out through the stomata. The process takes place day and night. The plants have a simultaneous process of photosynthesis which takes place at the day time only. Photosynthesis requires the presence of CO_2 which enters the plant-body through stomata. The association of plants is healthy for all animals in the day time because free oxygen is evolved due to this process of photosynthesis. There are some plants which can respire in the absence of atmospheric oxygen, their oxygen is derived by the disintegration of tissues, such plants are called anaerobic plants. There are other plants which can respire only in the presence of oxygen, they are called aerobes.

The anaerobic plants are yeasts while almost all plants are aerobic.

Experiment to show that plant respires.

A glass flask is filled with florets of sunflower and all green parts are rejected and some cotton wool supports the florets when the flask is inverted and fixed to a stand. The flask has also some sticks of caustic potash. The flask has a perforated rubber cork. The cork is sealed with the flask with paraffin wax so that no air can enter the flask. Through the perforation of the cork, a glass pipe of narrow bore passes into a dish of mercury at one end and the other end is inside the flask. The pipe is properly sealed with cork so that the apparatus is absolutely air-tight. After some 5 to 6 hours, the mercury rises in the tube. The significance is that the florets have respired and the CO_2 which is set free, is absorbed by the caustic sticks so that a diminution in volume of gas has occurred within the flask and as a result of that, mercury has risen inside the tube. This proves that respiration has taken place.

Excretion—

Animals and plants do not require all the substances introduced in their body. So everything which is useless to the organism must be eliminated which is known as **excretion.** Anything which is useless to the organism and has to be got rid of, is excretion. The higher animals take a large amount of food but the waste products which are not required for the body are rejected as faeces or excreta. The higher animals including fish, toad, reptile, birds and mammals have a definite excretory system. The blood stream carries the waste products of the body derived as a result of metabolism in the tissues which pass out as gas from lungs or gills as the case may be, in the form of CO_2. On the other hand, the blood is filtered and the nitrogenous waste products dissolved in water, pass out from the kidney through a passage called ureter. Therefore the kidney acts as a filter and the waste products pass out in the form of urine.

Another example of the way by which excretory products are eliminated is through the pores of the skin. The perspiration takes away the waste products but at the same time, it has a beneficial effect namely the skin is kept moist and is prevented from breaking down.

The lowest animal like amoeba has a contractile vacuole by which excretory products are eliminated.

Hydra has to eliminate through any part of their surface. The leech has pairs of nephridia segmentally arranged for the discharge of waste-products. The prawn has a definite excretory system which has their openings at the base of antennae.

The plants have generally no definite excretory system but in the higher plants, excretory products are generally stored up in the cortical region of the stem. In the plants, where bark is formed, the falling off of the bark, takes away the excretory products stored up in that dead tissue.

Sometimes the plants utilise the excretory products as a means of protection from the attack of animals. The animals once they feel the unwholesome smell will never turn their attention to such plants.

In conclusion, it should be remembered that the excretion is a product derived from the organism as a result of destructive metabolism generally.

Secretion—

The organism has to give out something either through some organs or tissues to carry out some function *i.e.*, anything which is given out for the benefit of the organism is **secretion.** Secretion differs from excretion in that, the former is beneficial whereas the latter is nothing but waste product.

The higher animals including man, have various secretory organs. Inside the mouth, whenever food is taken in, a juice comes out which is a secretion of the salivary glands. In the stomach, there are glands which secrete gastric juice which helps digestion. The pancreas also secretes a juice for helping digestion. These juices either run directly or through definite passages to mix up with the food to help digestion. But there are some, secretions from glands which have no so-called passage. These organs are known as endocrine glands. The thyroid, thymus, suprarenal, pituitary, spleen are examples of endocrine glands. The secretion from these organs simply mixes with the blood-stream and performs some of the most important functions of the body.

In conclusion, there are chemical agents called Enzymes which are always associated with the secretion which helps digestion. These enzymes do not themselves take part in the chemical reactions of the body. Thus there are fat-splitting enzymes which make fatty food fit for digestion and absorption.

The plants also secrete through cells to help digestion. There are some glands namely honey secreting glands in flowers which help the plant in pollination. In the case of fern and moss, definite chemical substances are secreted by the archegonium to bring about fertilisation. The cellulose wall of plant cells is a result of secretion of protopasm.

Storage of Reserve Material in Animals and Plants—

The living organism shows a foresight as it were, for the storage of food for future use. The animals store up food in their tissues; if for any reason, the supply of food is stopped or hindered. The commonest form of storage in the higher animals is Glycogen which is stored up in the liver for future use. The toad stores up glycogen in summer and leisurely uses them in winter. The other form of storage is fat which is also kept in reserve in the subcutaneous tissue and mesentery. The snakes store up, a large amount of fat under the skin for use in their hibernating period. The fat bodies found within the toad are also storage products.

Thus the form of glycogen and fat are the storage products in animals. Glycogen is similar to starch but more easily convertible into sugar.

Plants store up food either in their underground stems *e.g.* Tuber, Corm, Bulb or in their roots *e.g.* Sweetpotato. The form of storage is a variety of starch, protein and fat. Plants store up food in their seeds, which may be exalbuminous or albuminous, but human beings make use of such storage and turn them to their own use, thus robbing nature and making the plants less plentiful on the face of earth. The eggs of birds store up food in the form of yolk and albumin, is an instance where storage is found for the nourishment of the would-be developing embryo in animals.

Photosynthesis—

The word is derived from Photos meaning "light" and synthesis "to prepare." Photosynthesis means the preparation of organic food in the leaves with the help of chlorophyll and sunlight. The requisites for photosynthesis are sunlight, chlorophyll, carbon dioxide and water. Therefore photosynthesis can only take place in the chloroplastids which are always associated with green leaves. The carbon dioxide is supplied by the atmosphere and enters the leaves through the stomata. The water and inorganic substances come from the roots to the leaves. Therefore the leaf is the laboratory where organic substances are manufactured. The mesophyll of the leaves is richly supplied with cells containing chloroplastids and there is spongy parenchyma having plenty of intercellular spaces. The CO_2 of air enters through stomata and combines with the water which fill up the spaces of the mesophyll. The CO_2 readily combines with water forming an organic compound called formaldehyde and there is evolution of oxygen according to the equation :—

$$\underset{\text{carbon dioxide}}{CO_2} + \underset{\text{Water}}{H_2O} = \underset{\text{Formaldehyde}}{CH_2O} + \underset{\text{Oxygen.}}{O_2}$$

The formaldehyde immediately forms a combination of 6 molecules and Sugar is formed according to the equation :—

$$\underset{\text{Formaldehyde}}{6(CH_2O)} = \underset{\text{Sugar.}}{C_6H_{12}O_6}$$

This sugar loses a molecule of water and forms starch which is known as assimilatory starch.

$$\underset{\text{Sugar}}{C_6H_{12}O_6} \quad - \quad \underset{\text{Water}}{H_2O} \quad = \quad \underset{\text{Starch}}{C_6H_{10}O_5}$$

Whenever active growth is taking place, the starch is reconverted into sugar and supplies nourishment. The additional amount of sugar *i.e.* the amount that is not necessary for immediate use is stored up as starch and is known as **Reserved Starch.**

The chemical processes involved in the manufacture of the simple carbohydrates from the raw materials, carbon-dioxide and water, is a matter of great controversy. The process really consists of (1) a photochemical action, hence light is necessary; (2) a chemical action.

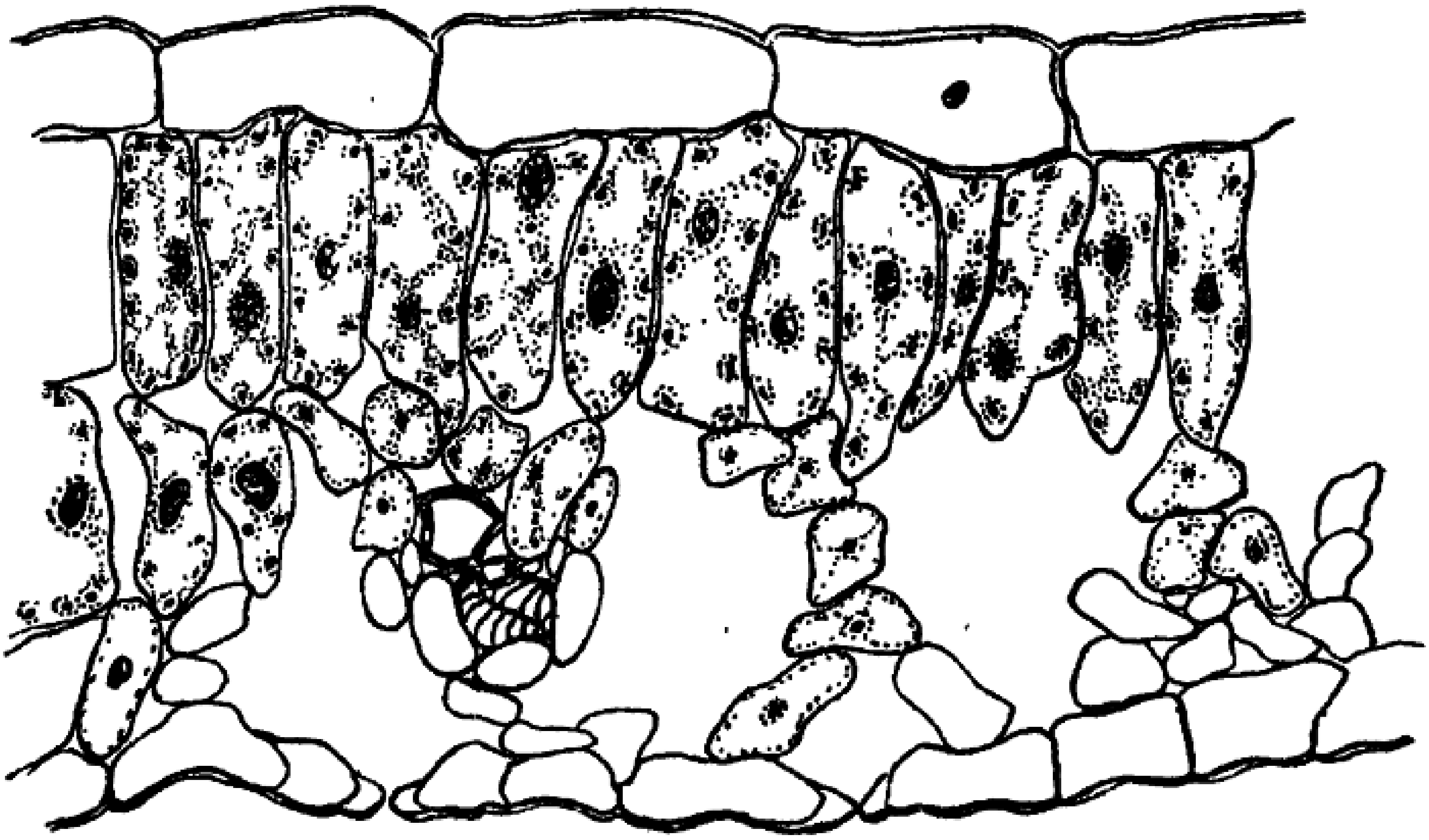
In 1843, Liebig suggested that there were several intermediate stages. In 1861, Butlcrow gave a good hypothesis for the production of carbohydrates.

In 1870, Baeyer developed the observation into a theory of photosynthesis.

In 1918, Willstatter and Stoll postulated the hypothesis which includes the production of formaldehyde.

Experiment to show that Oxygen is given out during the process of Photosynthesis.

Take a glass beaker and place a number of the pondweed called Hydrilla in it with water. Cover the plants with an inverted funnel and take a test-tube after filling it with water. Close the mouth of the test-tube with thumb and place it on the funnel. Place the apparatus in bright sunlight. Bubbles are given off periodically from the cut ends of the weeds and gradually the water of the test-tube is replaced by a gas.. Remove the test-tube and test the gas with a glowing splinter. The gas proves to be oxygen being a supporter of combustion.



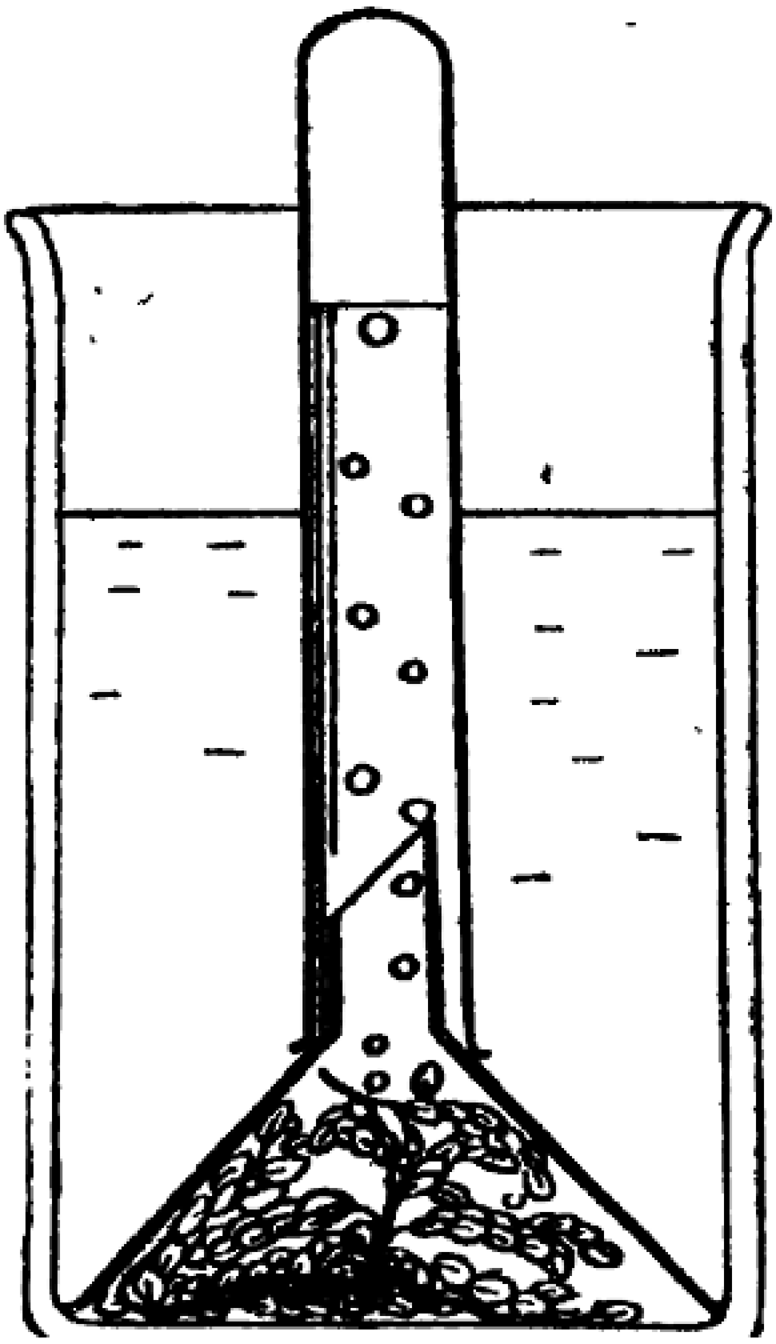
Section of green leaf showing chloroplasts in Mesophyll.

Normally, there is sufficient CO_2 in water and during photosynthesis, this gas is used up and O_2 is evolved.

Control experiment.

Set up another similar apparatus but boil the water before putting the water in the beaker. Cool it and put the plants and arrange like the previous experiment. The water in the test-tube should also be boiled and cooled. Place the apparatus in sunlight but no bubbles arise because by previous boiling all the dissolved CO_2 has been removed and so there is no evolution of oxygen as in the absence of CO_2, no organic matter is produced.

Take a green leaf which was exposed to sunlight. Wash it with warm alcohol to drive out chlorophyll. Then wash it with water and dip it in iodine solution. It turns blue showing the presence of starch. This proves that starch is manufactured by green plants during photosynthesis.



Experiment to Show evolution of oxygen during photosynthesis.

If the leaf was partly covered during its exposure to sunlight then the covered parts will not turn blue when placed in Iodine solution showing that the exposed parts are only able to manufacture starch which turn blue.

Comparison between Respiration and Photosynthesis.

	Respiration.		Photosynthesis.
	Takes place in all living cells.	1.	Takes place in cells containing chlorophyll.
2.	Raw materials are oxygen and food-stuffs.	2.	Raw materials are water and carbon dioxide.
3.	Takes place day and night.	3.	Takes place in day-time.
4.	Energy-releasing process.	4.	Energy absorbing process.
5.	Products are water and CO_2.	5.	Products are oxygen and food-stuffs.
6.	By this process, plant loses in weight.	6.	By this process, the plant gains in weight.
7.	It is a catabolic process.	7.	It is an anabolic process.

CHAPTER IV

STIMULUS AND RESPONSE IN PLANTS AND ANIMALS

The living protoplasm either in the animal or in the plant is capable of answering to any external change created in the form of stimulus. The protoplasm is said to respond to the stimulus. It is one of the characteristics of all living organisms. If the external conditions change also—the protoplasm is said to be sensitive. Thus in a dark room, a pot plant is placed and light is allowed to pass through a hole. The stem will try to move towards the source of light. The stem and leaves respond to the stimulus of light. If some algae be placed in water and at the bottom of the vessel, a light is placed, the plant will move towards the light.

The action of gravitation of the earth is manifested in the downward movement of the root. The root is sensitive to the stimulus of gravitation and moves towards the centre of the earth.

The stems of plants often turn towards the sun and this sensitiveness is known as heliotropism. The stem is called positively heliotropic while the root which moves away from the sun is known as negatively heliotropic.

The secretion of a chemical substance like Malic acid in the archegonium of fern acts as a stimulus and the antherozoids respond to it.

The more pronounced cases in plants is the stimulus of touch in the Telegraph plant (Bonchandal) which at once dances and closes the leaflets as a result of such stimulus. In some plants, the leaves and flowers open with the rise of the sun, *i.e.* they are capable of answering to the stimulus of light and in the evening the leaves and flowers close down. Some flowers like "Krishnakali," Tuberose (Rajanigandha) on the other hand, open only in the evening.

Some insectivorous plants like Drosera and Nepenthes are capable of secreting substances when insects touch their bodies.

Sir J. C. Bose has shown by his researches that the plants are capable of answering to stimuli and as a matter of fact, he has invented a delicate needle by which he injects stimulants and poisons into the tissues of the plant. He has recorded the effects of stimulants and has shown that the plant tissues can be stimulated like the animals. The effects of poisons had been a lowering of the life processes ultimately resulting in the death of the plant.

Therefore plants can and do respond to stimuli.

The animals show a variety of response to stimuli. The lowest animal like amœba, sends out its pseudopodia when it receives the stimulus of food-particle.

The Hydra, when it meets its prey sends out its wire from cnidoblast cells.

The Leech can respond to stimuli and has got a rudimentary nervous system.

The freshwater prawn has got a special balancing organ at the base of 1st antennule.

The higher animals can respond very well. If the leg-muscle of toad be dissected out with its nerve and a mild electric current is passed, it will respond by a series of movements which can be recorded.

There are some bats (Chiroptera) which are too sensitive to light. They can see only at night-fall and pass the daytime in hanging from trees like dead creatures.

The human body is sensitive to heat, cold and electric shocks. Drugs that are stimulants can stimulate animals whereas poisons can kill animals.

Movements in Plants and Animals—

The animals as already stated can move without any restriction but plants are more or less restricted in their movements.

The simplest amœba can move by pseudopodia. The Hydra can swim. The leech has looping movement and can freely swim in water. The prawn can swim and jump in water. The insects which are provided with wings are capable of moving for miles. The fish can swim indefinitely in water. The toad can move on land as well as swim in water and from their habitat both in land and water, they are called Amphibians. The mammals have their legs developed almost to a degree of perfection. The modern horse has got its limb specialised for movement. The birds generally are endowed with the highest form of movement for which their forelimbs have been modified into wings.

In the case of plants, movements are divisible into two sections :—

(*a*) **Taxism** and (*b*) **Tropism.**

Taxism means the movement of the whole organism.. Sometimes plants mainly unicellular move bodily either away or towards the source of stimulus. When chemical agents act for such stimulus, they are called chemotaxis *e.g.,* the movement of antherozoid towards the secreted malic acid of archegonium; Phototaxis, is the movement of the organism towards the source of light. All algae show phototaxis, these are attracted by weak light but move away from strong light. There are certain movements which are known as Autonomic *i.e.,* they occur from within, such as the movement of young leaves and other growth movements.

Tropism—

Tropic movement means the movement of a part of the plant and is induced *i.e.* caused by some stimulus. The various tropic movements are :—

(1) **Heliotropism,** (2) **Geotropism,** (3) **Hydrotropism** and (4) **Chemotropism.**

Heliotropism—

The stems of plants move towards sunlight whereas the roots grow away from light. The former is called positively heliotropic while the latter is called negatively heliotropic.

Geotropism—

The movement of roots towards the gravitation of earth is called Geotropic movement. The root grows towards the earth and is called positively geotropic. The stem grows away from the earth and is called negatively geotropic. If by any contrivance, the action of gravity is eliminated, the plants grow quite independent of this factor *i.e.,* the root does not go down and the stem does not go up. This can be manifested with the help of two instruments called Knight's wheel and Clinostat.

Hydrotropism—

This means the movement of parts of plants towards moisture or water. The root moves towards moisture and is called positively hydrotropic whereas the stem is negatively hydrotropic because it avoids moisture or water.

Chemotropism—

The movement due to chemical substances is known as chemotropism. The roots in such adverse situations like water-logged areas move towards the air for oxygen. The movement of pollen-tube towards the ovule by means of sugary solution is another example.

Nervous mechanism in Animals—

The animals have a very well organised system called the nervous system. It consists of a central station called the Brain which gains in complexity of structure as the animals evolve from lower to higher status. The highest development is attained by man, whose seat of intelligence in the brain has far surpassed that of any other animal. The central nervous system includes the Brain and the Spinal Cord. There is another system called the Peripheral system which includes the afferent and efferent nerves. The afferent nerves carry messages of the outside world to the brain which orders through the efferent system. The nerves are thread-like structures which ramify all over the body. The nervous system is peculiar in this respect that they have got the power of regeneration *i.e.,* parts which are cut off are capable of growing into new ones. The brain usually consists of two olfactory lobes, two cerebral hemispheres, two or four optic lobes, cerebellum and medulla oblongata. The medulla oblongata is continued as the spinal cord. The spinal cord runs through a bony column called vertebral column and the brain is protected by a bony structure called the Cranium which contains it.

The lower animals like the Prawn have also a nervous system consisting of Cerebral ganglia, thoracic ganglia and a double ventral nerve cord. The different portions of the body are supplied by branches from one or other of these ganglia. The leech has also a similar nervous system. The Hydra has some special cells called nerve cells but no such system.

The animals by their nervous mechanism control the different organs and functions of the body.

CHAPTER V

CHEMICAL CO-ORDINATION

There are various chemical actions in the body of the animal or plant which are kept in due order and which go by the name of chemical co-ordination. The chemical actions are in harmony *i.e.*, one is controlled by the other and there is not much or less of any activity. Thus there is a secretion in the mouth which is called saliva. In the stomach, there is the secretion of Gastric juice in which there is free hydrochloric acid. These secretions are never more or less in the healthy animal. The glands like Liver and Pancreas also secrete chemical substances which help digestion. There are certain glands which also secrete and help the animal to discharge its function. There are certain substances produced as a result of various chemical activities of the body, some of them are useful while others are mere waste products. Useful substances which in any way help to perform the bodily functions are known as **Secretions** while the waste products are known as **Excretions.** The gastric juice of stomach is an example of secretion while urine is an example of excretion.

The body of the animal is always undergoing some decay. The first and foremost of this chemical process is respiration. During respiration, a part of protoplasm combines with oxygen and liberates energy for the animal. Such a process of oxidation is really a process of combustion. It may be compared with the supply of fuel to the engine; the engine is the body and bodily protoplasm is the fuel. The loss of protoplasm is always compensated by a fresh supply of nutrition from the blood stream. While respiration goes on in the tissues, certain waste products are produced which are eliminated through different channels. The CO_2 is the most largely produced gaseous substance which readily dissolves in the blood and is carried by the venous blood to the lungs in the case of higher animals like the mammals, reptiles, birds, toads etc. to be exchanged for the atmospheric oxygen which again finds its way into the tissues through arterial blood. The fish has a different method of exchange namely they pass the CO_2 and absorb oxygen through their gills and the current of water which has dissolved in it these gases, supplies them with the necessary amount of oxygen and the outgoing current takes away the CO_2. Accumulation of too much CO_2 is poisonous for the animal as is exemplified by the process of suffocation felt when a large number of people are confined in small ill ventilated rooms or by people when they lie down in perfectly closed rooms for a period. They might die on account of excess of CO_2 and absence of atmospheric oxygen. Thus animals produce their poisons which must be eliminated from their bodies.

Chemical substances in the form of waste products might go out through the skin in the form of perspiration. The hibernating animals like the snake or toad can exchange oxygen for carbon dioxide through the skin. Respiration is the process which takes place in animals throughout their lives. Even in the foetus or in the embryonic condition while animals are still placed inside the mother, the exchange of gases takes place through the blood-vessels of the placenta. A very illuminating example is found inside the eggs of birds where the embryo develops. The eggs have spaces within the shells filled with oxygen meant for the developing embryo.

While the animals have constructive chemical secretions inside the various parts of the alimentary tube which make the food fit for the nourishment of the tissues. This is known as Anabolism. Side by side, there is destructive process mainly in the form of respiration by which CO_2 is produced. The balance is kept up by the supply of food. The extra amount of food is stored up in animals in the form of fat or glycogen in the Liver. Besides the above chemical processes, there are other chemical reactions in the body namely the formation of urine by which water and dissolved waste products in the form of urea and uric acid and salts go away from the body.

There are certain important chemical substances in the body which keep up the chemical balance. These are called Vitamins. The vitamins are necessary for the welfare of the body and are found in foodstuffs. Adulterated or decomposed food lose the vitamins and consumption of such substances is prejudicial to the body. The prevalence of Beri-beri is due to the absence of vitamins in our food. Fresh fruits, fresh vegetables, fresh fish and fresh meat, all abound in vitamins. Besides the vitamins, there are certain chemical agents in the blood of animals called Hormones, which regulate the various chemical actions of the body. These hormones also regulate the development and growth of animals.

The food of animals, consists of starch, sugar, fat, protein etc. There are chemical agents known as

Enzymes which help to split the above mentioned types of food and make them fit for digestion. These enzymes are very peculiar in that they do not take part in the chemical reactions but only help in the process. These are found both in animals and plants. Plants have a further complicated type of chemical action. They take in raw food materials from the soil which come up to the leaf through the xylem vessels and then the chemical reactions take place by which the CO_2, combines with water, in the presence of sunlight and chlorophyll. This chemical reaction liberates free oxygen and takes in CO_2. In water-plants too, this process of photo-synthesis is not wanting and we find the following chemical reaction taking place in the body of the plant :—

$$CO_2 + H_2O = CH_2O + O_2$$

(Formaladehyde)

$$6\,(CH_2O) = C_6H_{12}O_6$$

(Sugar)

$$C_6H_{12}O_6 - H_2O = C_6H_{10}O_5$$

(Starch)

As a result of photosynthesis, firstly formadehyde is produced which afterwards forms a compound called sugar. This sugar loses one molecule of water and forms starch.

There is another process namely respiration which takes place in plants both day and night. This consumes a considerable amount of plant protoplasm, supplying it with energy and liberating CO_2. In water-plants, the CO_2 is passed into the water. Plants also liberate various forms of etherial oils and odourous substances through their leaves, stems and flowers. They have no definite system for the passage of excretory products which are generally stored up in the outer parts and with their fall namely the fall of the Bark, the waste products are got rid of. Thus the living cells carry out the various chemical reactions of the body and their absorption, secretion and elimination depend upon the activity of the protoplasm. These changes are in harmony so that all the reactions are carried on in definite order and contribute to the due discharge of the different functions of both the plant and the animal economy.

CHAPTER VI.

REPRODUCTION.

Reproduction is a process by which new individuals are produced from already existing ones. The plants and animals reproduce in order to leave representatives in the world as all plants and animals after a period of growth must die. There are various processes of reproduction. A dog gives rise to a pup or pups, the method of producing a new pup is called reproduction. A plant flowers, the flowers develop into fruits and the fruits contain within them the seeds. The seeds on falling to the ground can give rise to a new plant. This is called reproduction. Principal methods of reproduction are asexual and sexual. The former takes place without the intervention of sex and the latter through sex.

The plants have all the principal methods of reproduction :—

Asexual method of reproduction is again sub-divided into, (*a*) Vegetative, (*b*) Asexual reproduction by spores. It occurs mostly in lower plants.

Reproduction—

Vegetative reproduction takes place by a separation of some vegetative part as by cutting, grafting, underground and creeping stems, adventitious buds etc. Vegetative structure means either root, stem or leaf. This method of reproduction is artificially used by agriculturists in the propagation of plants. The commonest example of vegetative reproduction is by cutting, grafting or layering of plants. The stem of rose is cut and added to a plant from which the upper portion has been removed. The rose plant develops into another plant. In the case of "Jaba," "Sajina" or Croton another plant is developed from a cutting of the parent plant. The rose also furnishes an example of layering, when a branch is bent and made to touch the soil, after a number of days, the point so fixed produces roots and is cut off from the main plant to lead an independent life. The roots of Patal (Trichosanthes) can produce other plants. Mango is generally cutivated by cuttings and graftings. The lower plants like the yeast reproduce by budding. The plant spirogyra vegetatively reproduces by separating a part of the filament. Mucor vegetatively reproduces in sugar solution by the production of oidium cells.

Asexual reproduction mostly takes place by the production of unicellular structures called spores without any sexual fusion. The Moss plant produces spores inside the capsule, each spore is capable of producing protonema on which the moss plant arises as a bud. The Fern plant produces spores on the under surface of its leaves. Each spore on germination can produce a Prothallus.

In some Algæ naked cells called Zoospores are produced which are meant for asexual reproduction.

In Mucor, asexual spores are produced within Gonidangium.

Sexual Reproduction—

This essentially consists in the production and union of two cells called Gametes. These Gametes are sometimes differentiated into male Gamete or Antherozoid and female Gamete or Osphere or Ovum.

When the gametes are similar the process of fusion is called conjugation and the cell produced after fusion is called Zygospore. When the gametes are dissimilar the result of union of Antherozoid with Oosphere is called Oospore. The process is called Fertilisation. There is a common term by which both the fusions can be denoted and that is Zygote. Zygote is the common name both for oospore and Zygospore. Fertilisation occurs in all higher plants, *e.g.*, in the flowering plants like Mango, Rose, Banyan, Pea, Maize &c., and in Fern, Moss. In the plants like Rose, Mango, etc., the male elements are inside the stamen in the form of pollen grains which germinate and produce gametes while the female element is contained within the ovule of the ovary.

The process of conjugation is found in the Mucor and Spirogyra.

Animals show the higher forms of reproduction and unlike plants sexual method is the universal method with the exception of cerain lower form of animals.

The essence of every act of reproduction is the origin, by the fission from the body of an organism of a reproductive body which will develop a young, the likeness of the parent. Sexual reproduction entails the union of the gametes whereas asexual reproduction is the production of a new individual without the union of the gametes.

In Hydra asexual reproduction takes place by the development of a multicellular bud which separates and forms a new Hydra. Thus reproduction by budding takes place in Hydra. Sexual reproduction also takes place in Hydra which essentially consists in the separation of two germs, *viz.*, ova and spermatozoa. The former is the female element while the latter is the male element. By their combination a new individual is produced.

In the Amœba, the asexual reproduction is the general rule and takes place by binary fission or division into two new individuals without any sexual congress. The Monocystis shows sexual conjugation and asexual formation of sporozoites in its life-history.

The Leech is an animal where male and female organs known as Testes and Ovary are found in the same individual. Consequently the animal is called a Hermaphrodite animal. The Prawn is a specialised animal having the sexes separate *i.e.*, unisexual but the peculiarity is that the openings of the sexual organs lie at the base of the third and fifth legs.

The vertebrates including Fish, Toad, and Guineapig have male and female animals separate. They have sexual Gonads which develop into Testes and Ovaries ultimately producing at maturity sperms and ova. These suitably unite and gradually form the young animal. As regards asexual reproduction, a solitary example can be cited in the Lower Chordata called Ascidians. The Ascidians might reproduce asexually by buds.

The Higher Invertebrates have asexual reproduction as in the insects where majority of animals are produced asexually in the form of workers. Sexual reproduction occurs but rarely.

In conclusion, the merits of sexual reproduction are far higher than those of asexual reproduction. In sexual reproduction the newly formed individual is more strong and better adapted for the world whereas asexual reproduction generally impairs the strength of the successive generations and makes them unfit for the world. Asexual Reproduction is a simple process and there is no specialised tissue for it. Sexual Reproduction has many failures and it is rather a complicated process. Sexual Reproduction completely replaces Asexual Reproduction in the higher animals because the tissues become specialised and are not able to produce new individuals from any and every part of the body. The puzzle of asexual reproduction lies in the case of ants, wasps and bees. The eggs of these social insects are unique in the animal kingdom, for they will develop equally well whether fertilised or not; they can be parthenogenetic but don't need to be so

Unfertilised eggs always turn into males, and fertilised eggs into females. Whether an egg is to be fertilised or not, is controlled by the Queen as she lays it. The Queen in the Bees, Wasps and Ants mates only once in her life-time during her "nuptial flight." The Queen stores up the sperms and controls its flow by a sphincter muscle. If she desires the muscle is relaxed and while passing down the oviduct, the egg receives some sperms and one of them fertilises it and the individual becomes a female while the majority are males as they are unfertilised and no fertilisation takes place in their case but they develop into males.

Parthenogenesis—

Some animals and plants develop gametes but the fusion does not take place. Generally the female gamete develops and behaves like the structure produced after conjugation. Parthenogenesis is a degenerate process and occurs in lower organisms. In the Spirogyra the gamete may develop parthenogenetically and behaves like a Zygospore. In the higher plants Parthenogenesis is rare and it is said that the jack-fruit is sometimes produced parthenogenetically under the soil and by the odour the fruit is detected under the soil.

The animals show Parthenogenesis in such types as the Ants. The individuals, namely the workers, are produced parthenogenetically. The nature of the gamete from which the parthenogenetic individual develops is an ovum. This occurs in various crustaceans (Prawn group) insects and worms. The female in the Green fly or in the Liver fluke reproduces for several generations without the assistance of the male. In certain Rotifers and Waterfleas fertilisation has never been observed. Parthenogenesis is a double process since the gamete is sexual but there is no fertilisation or conjugation; therefore it is asexual.

Alternation of Generations— /

Some animals and plants show two distinct stages in their life-history. The asexual form is generally alternated with the sexual form. This alternation of asexual and sexual form is known as the phenomenon of " Alternation of Generations." The lower plants generally do not show any alteration of generations. In the Moss plant the plant itself is the gametophyte and the sporophyte develops as a sporogonium upon it. Here the sporophyte is dependent upon the gametophyte but nevertheless there is alternation of the two generations *i.e.*, between two gametophytes the sporophyte is introduced. The Fern shows alternation of two generations, the plant itself is the sporophyte and the gametophyte is in the form of Prothallus. Thus the two generations are independent of each other. The asexual generation is the sporophyte producing spores whereas the sexual generation is the prothallus producing the gametes. In the higher plants like Rose, Pea, and Maize, the plants represent the sporophyte stage while the gametophyte is much reduced and is found after the germination of the pollen grain or in the formation of embryo-sac within the ovule. The higher plants have a prominent sporophyte and an inconspicuous gametophyte.

Thus alternation of generations is a constant feature of the higher plants i.e., the sporophyte alternates with the gametophyte.

The animals do not generally show such alternation as almost all the higher animals are sexual individuals. The exception is found in the Hydra and a related animal of the same group called Obelia. In Obelia the animal has an asexual form called the Polyp which produces two kinds of buds one gives rise to another polyp while the other form of bud is called the Medusa-bud which gives rise to free-living sexual individuals called Medusæ. This Medusa produces sexes in the form of male and female gonads in separate individuals. Thus in obelia there is distinct alternation of asexual or polyp form with the sexual or medusa form.

In Monocystis there are some authors who state that there is some sort of alternation of generations. The gametocyte represents the sexual and the sporozoite represents the asexual form. In the Malarial Parasite, the asexual and sexual forms have been correlated to be of the nature of alternation of generations.

Thus both in animals and plants there is the occurrence of the phenomena of alternation of generations although it is more pronounced in the case of plants than in animals.

CHAPTER VII

THE FORMATION OF THE EMBRYO IN THE FOWL

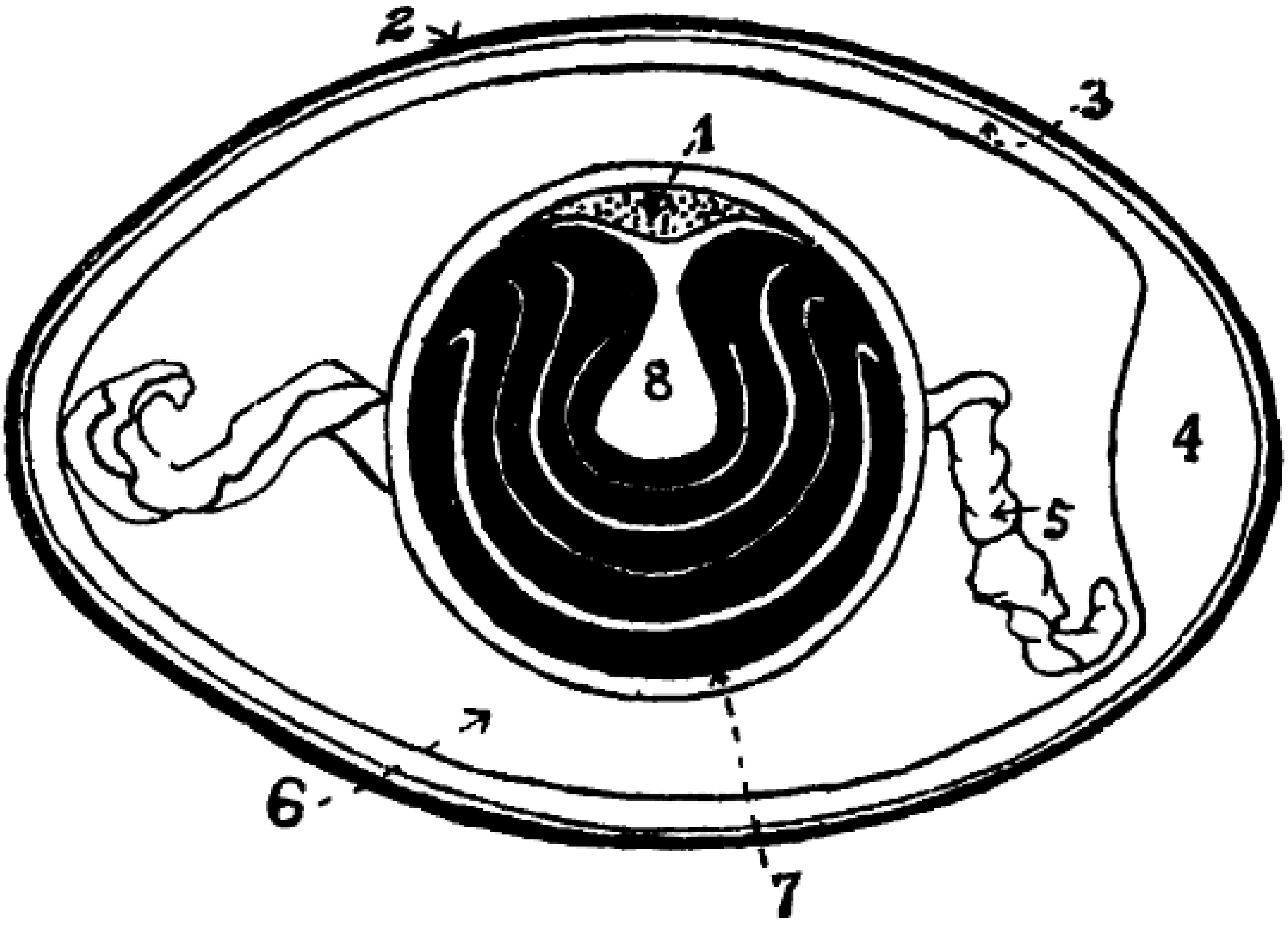
It is known that the hen lays eggs from time to time. There are two types of eggs and generally those of the market are unfertilised and some are fertilised. The ovum is discharged from the ovary and while the female gamete comes through the oviduct, it receives the coating of yolk and albumin. The fertilised hen's egg is developed by the union of the "mature" egg (the egg-cell after attaining its full size and forming its polar cells by unequal division) and the "mature" spermatozoon—*i.e.*, one of the male gametes formed by the final equal division and differentiation of a sperm-mother-cell. These sexual cells are called gametes and when the two opposite (male and female) gametes unite, they form a zygote.

All the ova of the hen are produced from the left ovary. The right ovary and oviduct disappear early in life. "Good layers" produce 100 eggs or more in a season.

1. Cleavage or segmentation of the Egg—

Cleavage is the process by which the zygote becomes divided into cells. The first few generations of cells are called **blastomeres.** The egg of a bird consists of cytoplasm distended very greatly by concentric layers of white and yellow yolk, except for a small area where the nucleus lies. This is seen as a white disc when seen from above and is known as the "germinal disc." The "germinal disc" gives rise to the greater part of the bird. The early cleavage begins in this area when the egg moves down the oviduct and is completed by the time the egg is laid. Firstly, two furrows appear at right angles to each other. Four radial fissures then appear about midway between the former furrows. In this way, the surface of the disc is converted into a mosaic of small polygonal areas, bounded peripherally by larger irregular divisions which form the **germ-wall.** The cleavage of the hen's egg is partial or **meroblastic** owing to the great mass of egg-yolk. The layer of the surface becomes double and the disc is then known as the **blastoderm.** At or about this time the egg is laid.

The egg of a fowl is more or less oval, the yolk is of immense size due to the deposit of a larger quantity of nutritive material and the germinal disc is pushed to one side. The ovum is covered by the Vitelline membrane. Then the white of egg or allumen surrounds the large ovum. The white portion consists of a solution of proteins and salts. Then the whole is covered by a double membrane. The two membranes enclose a space called the air-space for the respiration of the young embryo. Finally a shell encloses the whole structure. At the two ends of the egg twisted structures are found called Chalazae.



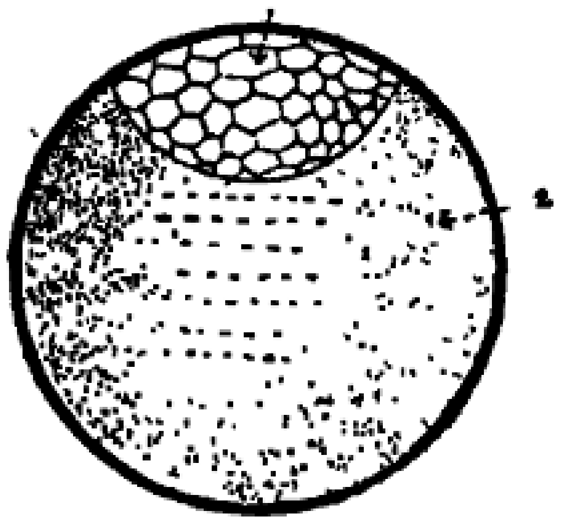
1. Germinaldisc,
2. Shell,
3. Double membranes,
4. Air space,
5. Chalaza,
6. Albumen,
7. Yolk,
8. White Yolk.

Therefore the egg of the fowl consists from the outside of the following structures :—

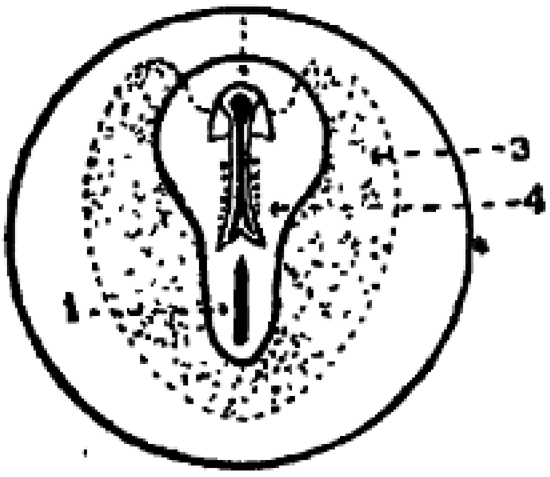
(1) Shell.
(2) Double membranes.
(3) Chalazae.
(4) Air-space.
(5) White of egg or Albumen.
(6) Yolk.
(7) Germinal disc.

2. The first day: Formation of the Germinal layers—

When the egg is laid on the ground, further development ceases until it gets the necessary temperature either from the hen or it may



Surface view.
1. Blastoderm,
2. Yolk.



1. Primitive Streak,
2. Head process,
3. Area opaca,
4. Area pellucida.

be hatched artificially with the help of an instrument called the **Incubator.** The blastoderm at the time of laying is a circular patch about 3·5 m.m. in diameter, on the surface of the yolk. Owing to its lower specific gravity the blastoderm remains uppermost however the egg be rolled over. It has a marginal white rim called the **area opaca** and a central circular translucent portion called the **area pellucida.** The blastoderm is not uniform in structure and in section appears to be of several layers. Among the blastodermic layers, there is formed a cavity containing a fluid called the **blastocoel.** As the disc expands, the upper cells are thinned out to form an outer germinal layer called the **ectoderm** or **epiblast** and a lower germinal layer called the **endoderm** or **hypoblast.** The cavity below the hypoblast is the **sub-germinal cavity** and corresponds to the archenteron of the frog. After the beginning of incubation, the blastoderm spreads rapidly. On the close of the 1st day, it is 20 m.m. in diameter and on the close of second day it has spread half-way round the egg. Complete enclosure of the yolk does not take place before the 17th day.

The Primitive Streak and origin of the **Mesoblast.**

An opaque band appears just after incubation in the posterior part of the pellucid area which becomed elongated and is known as the primitive streak. It grows backwards and the pellucid area also elongates simultaneously. The primitive streak while elongating shows a fine transparent line running down its centre. This is caused by a groove called the **primitive groove.** The primitive groove has a small pit in front. The primitive streak is a keel-like band of proliferating epiblast and the hypoblast does not take part in its formation. The cells that the primitive streak buds off between epiblast and hypoblast is a paired sheet of loose tissue. This tissue is the **mesoderm** or **mesoblast** and this germinal layer is formed by the primitive streak by budding of the epiblast.

Fate of the Germinal layers—

The epiblast gives rise to the following organs and tissues of the chick :—

(*a*) The epidermis and its appendages (feathers etc.) ; the nervous system ; the sensory epithelium of the sense-organs ; the lining of the month and of the cloaca.

(*b*) The hypoblast gives rise to the epithelium of the alimentary canal and of the glands that spring from it.

(*c*) The mesoblast gives rise to all the connective tissue. vascular. muscular and Skeletal Structures as well as to the urinary and reproductive organs.

The Notochord and medullary folds—

An area develops in front of the primitive streak towards the end of the 1st day which is a forward continuation of the primitive streak. This is called the head—process and ultimately forms the **notochord** or forerunner of the vertebral column. Blastoderm in front of the primitive streak at the 16th hr. of incubation shows that the epiblast is several cells thick and is called the neural or medullary plate. The neural plate folds to form the first trace of the nervous system called the **neural or medullary folds** ; the centre or axis of the head-process possesses for the hinder part of its length a rod of cells called the notochord. The mesoblast spreads out as a pair of wings. At the end of the first day, the embryo is all head having only the nervous system of the head and the notochord.

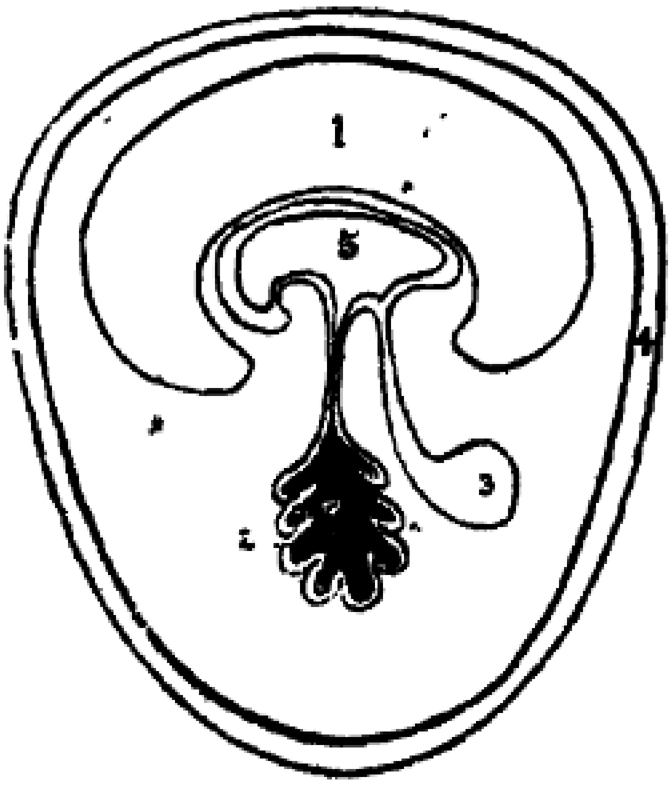
3. The Second day—

On the second day, the head fold has the effect of folding off the anterior region of the embryo from the underlying yolk. The blood-vessels develop on the surface of the yolk and a circulation of blood, within and without the embryo is established. Somites increase in number on either side of the nervous system and notochord. These somites give rise to voluntary muscles (except those of the head), the axial skeleton of the body and the dermis. By a horizontal slit in the lateral wings of the primitive streak, the mesoblast from which they are cut off becomes hollow. This cavity forms the coelome or body—carity of the future chick. The outer wall of the cavity forms the body wall of the chick and is called the *somatopleure*, while the inner wall forms the gut or **Splanchnopleure.**

4. The Third day—

By the union of the head-fold, lateral-folds and tail-fold, a structure is formed called the amnion. This is one of the foetal membranes. On this day, the rudiments of the internal organs of the adult are established. From the hind-gut, there develops on the 3rd day, a pouch like outgrowth called the allantois. The allantois is also a foetal membrane and is cast off at the time of hatching. It is highly vascular and the allantois acts as a respiratory organ of the embryo by absorbing oxygen from the air-chamber.

The heart on the 3rd day of incubation is like a S-shaped loop which ultimately forms the auricles and ventricles.



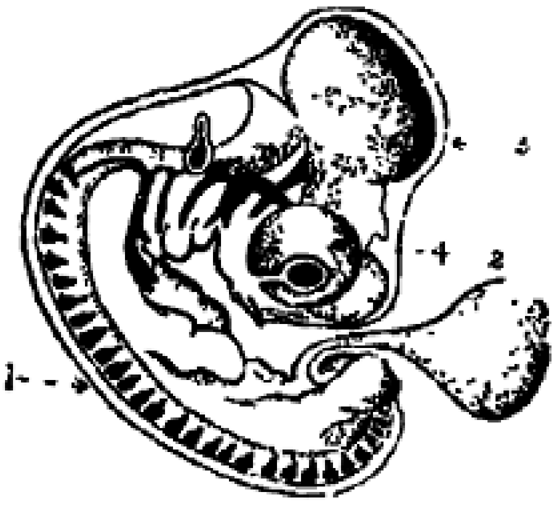
1. Amnion,
2. Yolk-sac,
3. Allantois,
4. Chorion,
5. Embryo.

5. The Fourth day—

The egg albumen is restricted in area. The wings and legs appear. The kidney and ureter are developed.

6. The Fifth day—

The embryo is strongly bent. The cartilaginous portions of the skeleton appear.



1. Embryo,
2. Allantois,
3. Headfold,
4. Eye.

7. The Sixth day—

The characters of a bird appear in the wings, feet, skull and alimentary canal.

8. The Seventh day—

The amnion and allantois show contractile movements. The head now grows less rapidly than the body.

9. The Ninth day—

Feathers appear through the skin.

10. The Twentieth day—

The beak perforates the inner shell-membrane and the chick breathes air. The lungs breathe air.

11. The Twenty-first day—

The chick is hatched.

CHAPTER VIII

ORGANIC EVOLUTION.

Formerly it was thought that God created everything as it is, but later on scientific observations led to the **Theory of Evolution.**

The creation of animals and plants independently without a gradual development is known as the **Theory of special creation.** It is in fact the literal interpretation of the story of creation as set forth in the first chapter of **Genesis.** The theory of special creation was supported by the **Christian fathers,** though an honourable exception must be given to St. Augustine, who would have taught otherwise. The theory was fated to suffer a severe shock from the discoveries of fossils in the rocks. These fossils were evidently the remains of an older population and the puzzle was how to account for them.

An explanation was suggested for these fossils by the great naturalist **Cuvier** who formulated the theory of catastrophism.

Theory of catastrophism—

Cuvier (1769-1832) suggested that the world had been the scene of a series of vast local cataclysms by which the plants and animals were exterminated but in certain cases preserved in the rocks. After each catastrophe the region was repopulated, not by a new act of creation, but by the migration of animals and plants from surrounding areas which had not suffered.

Evolution means the gradual development of complex highly organised animals or plants from simple pre-existing animals or plants. There are various evidences in support of the theory of evolution.

1. Structural and Anatomical—

The simplest animal Protozoa as Amœba gives place to Hydra with two body layers only. Then comes the next group of Annelida of which Leech has three body layers and gradually the highest complexity is reached in the mammals. The organs also show gradual evolution from simple to complex type. The paired organs like the forelimbs of birds, toad and guineapig are built on the same plan and hence they are the modifications undergone by the forefathers of those animals in course of time according to circumstances of life. The wing of pigeons is used in flight but is not functional in the Newzealand kiwi bird where only a remnant of the wings is found. The evidence is that the same muscles that are active in pigeon and the same type of bones are found in both the animals. The teeth of guineapig are necessary for the very existence of the animal but in the Whalebone Whale the teeth are only present in the foetus and are lost after birth. The conclusion is that the whale had ancestors with functional teeth but which are lost in the course of evolution.

By the study of comparative anatomy, it was realised that certain structures of the bodies of different organisms showed a great similarity one to another and were indeed homologous; that is, resembled each other in their architecture and corresponded to each other in their development. As an example, let us take a series of forelimbs of some backboned animals. The arm of a toad, the paddle of a turtle, the wing of a bird, the flapper of a whale, the wing of a bat or the arm of a man, though serving very different functions, are all built in the same pattern.

It is true that all are adapted in particular ways to their various uses, but in essentials these forelimbs are arranged on identical lines. Any interpretation of these facts is difficult other than the one that they are due to relationship. Again, it is found that the number of vertebræ in the necks of mammals, is with two exceptions always seven; the long neck of the giraffe and practically the non-existent neck of the whale have exactly the same number of bones. Evolution explains this fact but on no other theory is it explicable.

Vestigial structures—In the bodies of animals there are remains of structures which are now functionless which give a proof of the animals' ancestries. The remains of the second and fourth digits in the limbs of the horse are examples of such vestigial structures; the tiny bones in the body of the whale, representing the hindlimbs; in the baleen whales the teeth which never cut the gums.

2. Embryological—

The study of embryology affords good evidence towards evolution. The development of an individual organism repeats in a very brief form, from the early stage of fertilisation right up to the fully formed animal, a series of changes which had occurred during the development of the particular kind of animal through thousands of years. This development of race had many changes and modifications in life which is represented in a miniature form in the development of the embryo. This is known as the "Theory of Recapitulation," or "Biogenetic Law." The embryos of higher animals generally repeat the characters of lower animals in the foetal life. The development of a mammal shows Visceral arches and clefts comparable to the Branchial arches and clefts of the fish.

Next, the characters of an Amphibian are seen and further development shows the nature of Reptilian characters. Finally the Mammalian characters appear.

The development and metamorphosis of the Toad show the gills in the tadpole stage resembling the fish and strictly speaking the tadpole is more like a fish than a toad. It proves clearly that in evolution fish-like forms have given rise to the Amphibian stock.

From embyological study, let us take the example of the heart. In the fish, this organ consists of an auricle and a ventricle. The auricle receives impure blood and the ventricle drives it to the gills for purification. In the amphibia, the auricles become divided into two while in the reptiles the ventricle is divided partially—except in the crocodile where the division is complete and the heart is four-chambered. In birds and mammals, the four-chambered heart with two auricles and ventricles is the rule. During development, the hearts of mammals and birds pass through the stages outlined above; there are the fish and amphibian heart stages in every developing mammal. In the same way other organs of the body, such as the kidneys and the brain, demonstrate by their development their evolutionary history.

3. Geographical—

Animals and plants often are separated by wide oceans and mountains but nevertheless they originated from common ancestors so their similarities are often noticed although occurring in widely separated areas. The reason is that the surface of the earth had undergone changes and oceans have arisen where mountains stood thousands of years ago or mountains and plains have arisen where once oceans stood in ages long gone by. The flora and fauna of south Africa have similarities with that of India. Japan has similar flora and fauna with that of Europe. Besides the similarities another question has to be met. There are some forms that are peculiar to a land and generally do not occur anywhere else. These are known as endemic forms. The Australian Anteater or the Kangaroo is an example of endemic fauna. In China there occur a Gymnospermic plant which is endemic to that country. The explanation is perhaps that the land is very primitive in its history of the world and has been cut off from other parts of the world for a very long time so that its distribution is restricted to that particular area of land.

Let us discuss the geographical evidence which impressed Darwin so much. During Darwin's voyage in the Beagle (1831-1836) the Galapagos, a chain of islands some 600 miles west of South America, were visited. He collected as many animals and plants as could be collected and on classification found that each of the islands had its peculiar animal population. The species of one island though distinctive were similar to those of another and the general fauna of all the islands resembled that of the adjoining mainland. The explanation was that the species on the islands and on the mainland were blood relations claiming their descent from a common ancestor. Thus Darwin's attention was drawn to the question of the origin of species.

It is probable that at an earlier period in the earth's history these islands were joined together to form one large land mass which was itself once connected with the West Indies and Central America.

There was then presumably a much smaller number of species than to-day and they were distributed over the entire region. After separation from the American continent the species became isolated through the breaking up of this landmass into smaller islands. Subsequently these solitary groups of animals became differentiated into the several forms now characteristic of the various islands, showing descent from a common ancestor with eventual specialization. Australia affords another example. There was one time in the earth's history when only the marsupials or pouched mammals were found. Later on Australia was separated by oceanic waters from the continent of Asia. No aggressive mammal could come to Australia due to the barrier of water and thus the marsupials flourished and are living upto this day.

4. **Palaeontological—**

Plants and animals are preserved in the layers of the earth either as impressions or as calcified lumps. These are known as fossils. The Earth has different layers called strata. These strata have been formed by deposition through thousands of years. The age of the Earth is broadly divided into three periods, *viz.*, Paleozoic, Mesozoic and Tertiary corresponding to very early, middle and modern ages. Any fossil found in these strata can be approximately identified to that particular age. From the study of the fossils variations are seen which are co-related with the present forms and related types are known to be ancestors of the present forms. The present horse had various types of ancestors and gradually the present form has appeared. The mammals and other vertebrates are preserved as fossils more easily as they have bony skeleton but the invertebrates are less available as fossils except some which had hard external coverings on account of their soft bodily structures which are unsuitable for preservation.

5. Experimental—

New forms of animals arise from original simple types. The rock pigeon or the wild pigeon has given rise to the thousand and one types now available as fantail pigeons, pouters, Jacobins etc.

6. Serological test—

Freudenthal and Nuttal carried out blood tests to show the kinship of the various species of back-boned animals. They found out that the blood of a rabbit when introduced into the blood stream of a near relative such as a hare, the two kinds of blood mixed freely together. If the rabbit's blood was introduced into an animal not so closely related as for example a dog, a definite antagonism was produced, causing the destruction of the red blood corpuscles (haemolysis). Such tests can bring out the relationship between two animals specially their nearness.

THEORIES OF ORGANIC EVOLUTION

History of the theories of evolution—

The conception of organic evolution really began in the nineteenth century through the work of Charles Darwin. But the theory was foreshadowed long before the publication of the "origin of species."

Early Greek theories—It is interesting to note the views of ancient Greeks regarding evolution. Five centuries before the Christian era we find Anaximander dealing with the problem. Empedocles (495-435 B.C.) taught not only the relationship between the different species of animals or plants but said that nature was continually trying new types, some better fitted to environment whereas less fitted types were ultimately dead thus foreshadowing the theory of the survival of the fittest.

Heraclitus and Democritus believed that all things were in a state of continual change. Aristotle was the founder of the genuine scientific method and father of natural history. He believed in a gradation from the lowest organisms to the highest and that man was the highest point of one long and continuous ascent.

The fact remains, however, that not until the coming of such men as Linnæus, Buffon, Erasmus Darwin, Lamarck and Charles Darwin was real progress once more made and from then onwards the advance never ceased.

Linnaeus—This great swedish naturalist was born in 1707. Linnæus was sent to a good school, but his

BIOLOGY FOR BEGINNERS

BIOLOGY

GENERAL INTRODUCTION

Biology consists of the study of **Botany** and **Zoology. Botany** deals with the study of plants and **Zoology** with the study of animals. Biology may be shortly described as the *Science of Life.* Plants are plentiful and varied in nature so also are the animals. It is one of the basic Sciences which makes human knowledge approach perfection. There are various aspects from which the study of life can be approached.

Important branches of Botany and Zoology—

The study of outward form is known as **Morphology.** Morphology is again divided into **External Morphology** and **Internal Morphology.** Examples will clear the idea :—The colour of a flower, the nature of the leaves, the presence of hairs on the body of a plant or animal are all characters of *external morphology.* The internal structure of plants or animals is *internal morphology.* The study of internal morphology with the unaided eye is called **Anatomy.** The study of internal morphology with the **Compound Microscope** is **Histology.** The study of biology requires a special instrument known as the **Compound Microscope.** Microscopes magnify simple and small objects in order that these small things progress was unsatisfactory and he spent all his time in collecting natural history specimens. Linnæus is best known for his classification of animals and plants; he was a firm believer in the origin of species by "special creation," though he admitted the production of "post creation" forms by hybridization.

Buffon—He was also born in 1707. As an investigator, Buffon does not rank high for he left few original contributions to science; his mind was philosophically rather than scientifically inclined. He was a firm believer in the process of evolution.

To Buffon environment was all important as modifying the structure of animals and plants and he believed the modifications so produced were inherited.

Erasmus Darwin (1731-1802)—This country physician and naturalist, the grandfather of Charles Darwin was the greatest of Lamarck's predecessors. In 1794, he published a book, "Zoonomia" in which he stated ten principles regarding the course of evolution. E. Darwin's views are similar to Lamarck.

Lamarck (1744-1829)—His influence on the theory of evolution is second only to that of Charles Darwin, indeed by some modern biologists his theories are accepted, while those of Darwin are discredited. Lamarck was intended for the church but he disliked it and finally joined the army. Later on, being unfit for military life he took up medicine but changed to botany, to which study he remained attached until 1794, when he was fifty years of age. He changed from botany and took charge of the department of invertebrates. This change had a profound influence in shaping his ideas.

Lamarck's Theory—

Lamarck published his theory in 1809. His views are :—

(1) Use and disuse of parts.

He says that organs or parts of the body that are mostly used are preserved and develop while those parts that are in disuse undergo decay and finally are lost. Secondly, the changes on account of use and disuse are transmitted to the offspring as a character. In the plants environment plays a very important part for the fixing of a new character.

The giraffe has a long neck and the forelimbs are much longer than the hindlimbs. The giraffe lives in a part of Africa which has less vegetation and consequently the animal has to live upon the leaves of trees which it cannot reach unless the neck is long and the forelimbs are suitably so. The constant care for such endeavour has resulted in the long neck. The forefather of the snake had stout body and two pairs of long limbs. The subsequent life in this world necessitated longer body and disuse of limbs which have been gradually lost in the modern snake. The new characters which have appeared pass from generation to generation according to this theory. But this theory is not accepted by many Biologists.

His theory was that modifications, that is variations, in the structure of plants and animals were due to some force exercised during their life. In the case of plants, environment was the chief agent; thus soil conditions, altitude, moisture, heat and light were important factors inducing variations which were inherited. The shape of irregular flowers was supposed to have been caused by the strains induced by the visits of bees and other insects during their search for honey.

In the case of animals Lamarck regarded the environment as undoubtedly playing a part but considered that the most fruitful cause of variation arose from the effect of use and disuse.

During the last fifty years, the theory of Lamarck that useful characters when developed are transmitted by inheritance is controverted and denied.

Darwin's Theory—

In 1858, Charles Darwin simultaneously with Wallace gave an explanation of evolution as well as of Natural selection. Darwin is regarded as the father of evolution. He brought experimental data as proof of evolution. Previously people believed that God created everything all at once as stated before. Darwin's theory had many setbacks as there was a time when people burnt down places where Darwin's Theory was advocated, but truth conquers all difficulties, and modern scientist appreciates and believes in the theory of evolution. Darwin's theory had undergone many changes but still the basis remains and the science of Biology has a permanent debt to this genius of evolutionary theory. Two main points of Darwin's theory are :—

(1) **Struggle for existence** and (2) **Variation.** Darwin's theory of natural selection advocated that animals increase in great numbers in this world but there is not sufficient space for all of them ; so those who are more fit will survive and those unfit will die away from the face of the earth. This is known as struggle for existence.

If a plot of garden land is allowed to run to waste *i.e.*, if weeds are allowed to appear, then gradually the weeds will cover the whole surface and the garden plants will die out. The explanation is that the weeds are more fit to fight for their existence in the world than the garden plants.

Another factor of Darwin's Theory is that Variations or slight changes gradually appear in the organism but it does not admit that the variations are passed from generation to generation.

Among animals a severe struggle for existence is always going on. Large numbers of ova are produced in the lower animals. Some are eaten up by other animals, others do not get a favourable place and only a few can develop into maturity. Among higher animals the fight is seen between carnivorous animals and their prey in which the latter develop their power of flight, alertness etc., to protect themselves.

As an example of variation Darwin took much interest in the pigeons. The various types of pigeons are descended from a common stalk the wild blue rock pigeon. Man tends animals which attract his fancies.

The variation which appeals to him becomes more numerous by his care. The various domesticated animals like dogs, goats, sheep etc. have all originated by such variations.

Life of Darwin—

He was born at Shrewsbury on February 12, 1809. The Darwin family is an example of inheritance of mental capabilities. Charles Darwin was the grandson of Erasmus Darwin, the author of the famous book "Zoonomia;" his father was a physician. Sir Francis

Galton, the founder of the Science of Eugenics, was Darwin's cousin. Darwin's sons have attained eminence in the scientific world.

Darwin's early years gave no indication of his extreme intellectual ability. He went to study medicine but left the course to study theology prior to entering the church. He took a degree but he devoted the major part of his time in natural history pursuits. The turning point of his life came when he was appointed naturalist on the "Beagle" which was going on a surveying expedition under the command of Captain Fitz-Roy. The voyage lasted from 1831-1836 and Darwin collected much valuable material. He was greatly hampered for nearly forty years with a constant illness. For nearly twenty years Darwin collected evidence regarding the Origin of Species. In 1858, he published his first paper under unusual circumstances. In that year Darwin received from Alfred Russell Wallace, a letter asking him to read and criticize the theory Wallace had come to concerning the origin of species. To Darwin's surprise he found that the theory was entirely identical with his own and he was practically fixed in his mind to withdraw all claim and to publish Wallace's essay. Happily however due to Hooker and Lyell, a joint paper in the names of Darwin and Wallace was read before the Linnæan Society in London in 1858. In the following year, "The origin of species" was published. It is curious that the same book, Malthus's essay "On Population" gave to both of them the idea of Natural Selection.

There are three fundamental principles underlying Darwin's theory, variation, heredity and natural selection, the last being the central point of the whole idea.

Variation—

The members of a family are not all alike at birth. While collecting animals and plants one notices the variation between members of the same species. The variations are always found and Darwin frankly admitted his inability to explain how they arose.

Heredity—

It is found that variations found in animals and plants pass from one generation to the next. Darwin himself believed such characters might be inherited: a view not widely held to-day; but the ultimate solution of the problem will not materially alter the Darwinian theory.

Natural selection—

In the case of gardeners or poultry farmers, the breeder keeps the forms which he desires and destroys the rest. This is artificial selection. The selection of species by nature is natural selection.

The numbers of individuals composing any species of animal or plant are constant but the rate of increase is often very great. Prof. Punnett calculated that in the case of a Rotifer which is barely visible to the unaided eye, if after sixty-seven generations produced in a year all the Rotifers could be saved, then they would have formed a sphere greater than the earth. Darwin calculated and assumed that the elephant first breeds at 30 years and lives upto 100 years and has six young in the interval period then after 740-750 years, if all the animals survived there would be about 19,000,000 elephants descended from the original pair.

It is evident therefore that in Nature there must be some factor keeping down numbers. Since the space and food-supply available for all animals and plants are limited, it follows that there must be a proportion of them, that are killed before reaching maturity. There is, in fact, a struggle for existence. " It occurs between organisms of the same species ; between friends and foes, and between living creatures and their environments with the inevitable result that the numbers are reduced and increase in population is checked. Natural selection is a passive agent, it cannot create, it can only destroy or preserve. It is the inevitable outcome of the interaction of variation and the struggle for existence by which the fittest survive.

The effect of Natural Selection as an evolutionary process, as Lull summarizes it, is :

(*a*) Under new conditions harmful characters will be eliminated by selection,

(*b*) Beneficial characters are intensified and modified.

(*c*) The great body of characters neither harmful nor beneficial will not be modified, but will persist through heredity.

Examples of Natural Selection :—

(1) The sharp eyes of the hawk have arisen by Natural Selection eliminating hawks born with weak or defective vision.

(2) In August 1909, a heavy snowstorm destroyed some trees in Johannesburg but the Deodars from the Himalayas survived.

De Vries' theory—

This theory advocates that new species arise by "mutation" or "saltation." Mutation means the appearance of a new type at once without accumulation of small distinctive changes. It is a jump and says that beneficial characters are transmitted to future generations while harmful characters are eliminated. The author of this theory carried out various experiments with plants. Although natural selection has a very prominent part in the fixing of the mutation but that is not openly admitted. The loss of limbs of snake can be explained by this theory as a loss at once and the character is transmitted to modern types of snakes.

CHAPTER IX

BIOLOGY FOR BEGINNERS

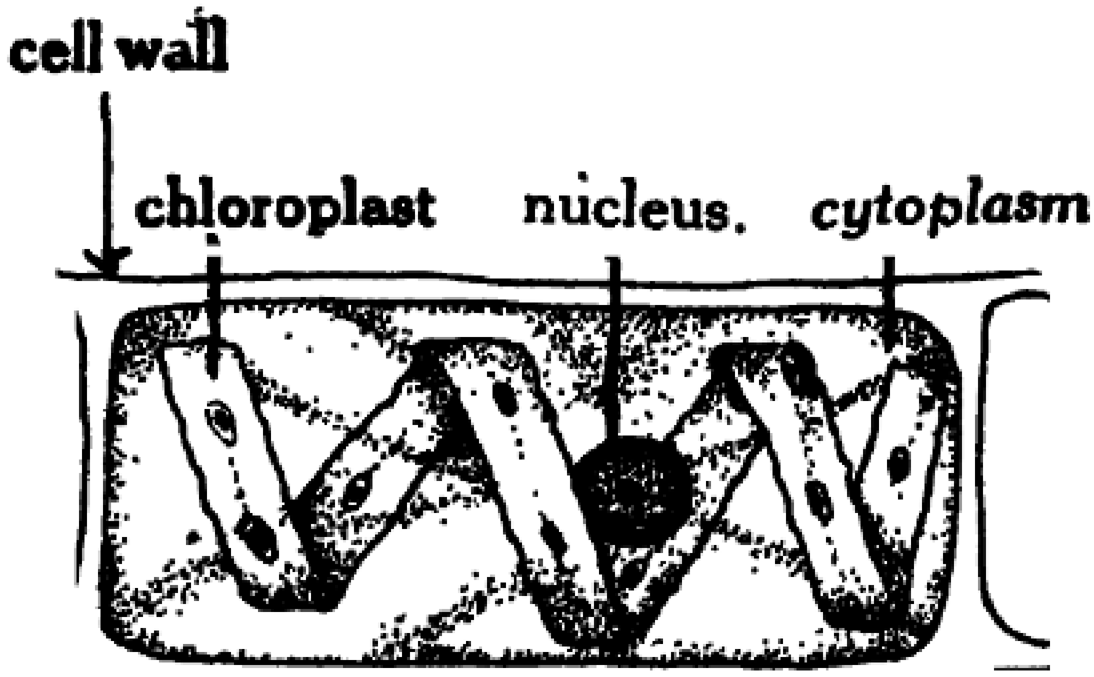
BOTANY

Divisions of the plant kingdom—

Plants are found everywhere on the face of the earth. The mountain peak or the depth of the ocean has its peculiar flora. The variety of plants may not be known to the general reader but once the pages of botany are turned, the richness of variety comes to one's mind.

The plant kingdom has been grouped into the following main divisions:

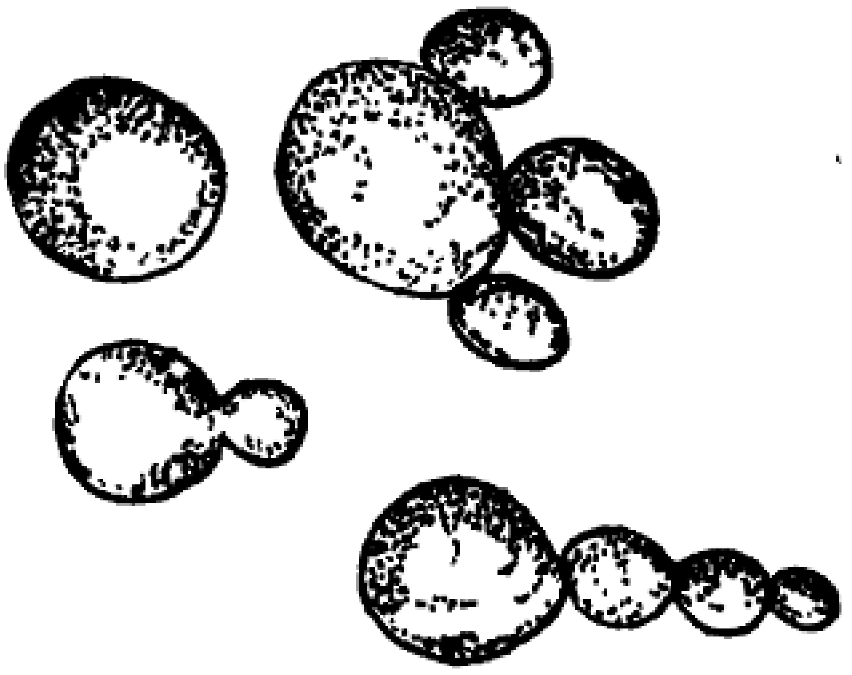
The first and lowest division is **Thallophyta** or **Thallophytes.** It includes simplest forms of plant life having a body which either consists of a single cell or many-celled in structure. Such a body is not differentiated into organs such as root, stem and leaves. This type of plant-body is called a **Thallus.** Some of the



Spirogyra

thallophytes possess chlorophyll and therefore green in colour while others lack this pigment. The former forms a definite group called the **algae** and the latter **fungi.** Examples of algae are pond scum such as **Spirogyra** and many seaweeds found in oceans and seas.

Toadstools, Yeast, Breadmould are familiar examples of fungi. In many seaweeds, the thalloid body is often differentiated into root-like, stem-like and leaf-like organs.



Yeast

In the second division of the plant kingdom, the **Bryophyta** or **bryophytes,** one notices a progressive differentiation of the vegetative body from **thallose** to **foliose** form with forms having distinct development of the shoot system, true roots being entirely absent from this group. Common examples of bryophytes are **Liverworts** and **Mosses** which are found plentifully on rocks in temperate regions and on walls, grounds, on roofs and on barks of trees, specially in the rainy season.

The **pteridophyta** or **pteridophytes** comprise the third great division of the plant kingdom. They differ from the other two divisions in that they have their vegetative bodies differentiated into roots, stems, leaves and a well developed conducting system. They also differ from the next higher group, the **spermatophytes**

Moss

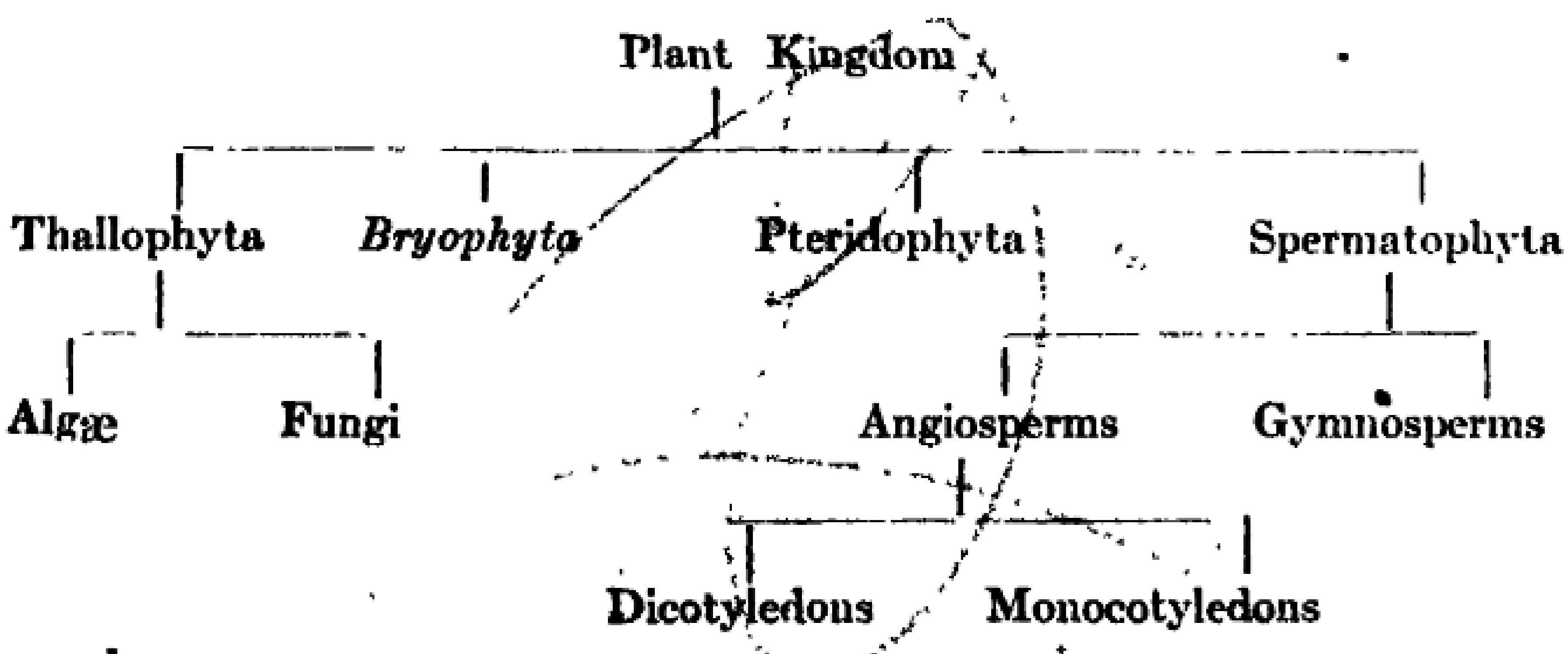
or **spermatophyta** by the fact that they do not produce seeds. Ferns, Horsetails, Clubmosses which are so abundant on hills and in the tropical forests are familiar examples.

Other important distinguishing features of Thallophyta are :—

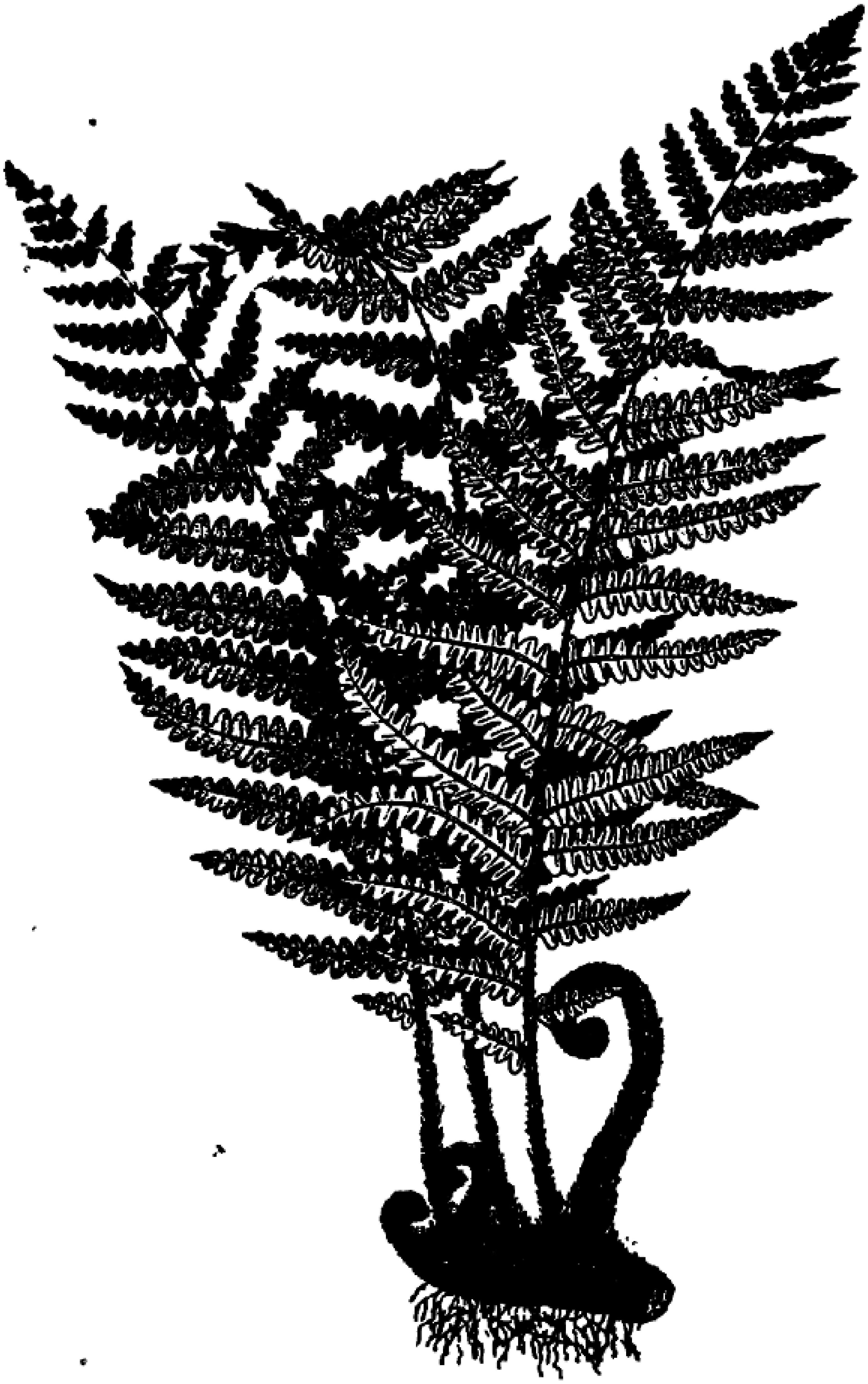
(1) Sex-organs mostly one-celled,
(2) Sporangia always one-celled,
(3) The zygote nerve develops into a multicellular embryo while still within the female sex-organs.

In the fourth and the highest division of the plant kingdom, the **spermatophyta** or **spermatophytes** one notices complete differentiation of the plantbody into the

vegetative organs such as *roots, stems* and *leaves* like the pteridophytes and they also possess a well developed conducting system. But the most important feature which distinguishes it from other groups is the production of seeds. The term spermatophytes means seed-bearing plants. The two sub-divisions of the spermatophytes are **Gymnosperms** and **Angiosperms.** In the former the seeds are naked *i.e.,* not enclosed in a fruit but in the latter the seeds are enclosed within the fruits hence these are close-seeded plants. Familiar examples of gymnosperms are Pines, Cycads, Cedars etc. The angiosperms are further sub-divided into two groups, the **Monocotyledons** and the **Dicotyledons.** The monocotyledons are represented by plants like Bamboo, Rice, Maize and other cereals, Orchids, Bananas, Grasses etc. The Dicotyledons include plants like Gram, Pea Bean etc. The essential differences between the last two groups will be discussed in subsequent chapters. Table of the divisions of the plant kingdom.



The Thallophyta, Bryophyta and Pteridophyta form the great group of **Cryptogams.** The cryptogams do



Fern.

not produce seeds but produce unicellular structures called the spores. The spermatophyta produce seeds. The old definition and divisions of the plant kingdom into Phanerogams and Cryptogams have been partly modified. The phanerogams were defined to be flowering and the cryptogams non-flowering plants but recently it has been discarded.

CHAPTER X

SEEDS

General structure—

Every seed contains within it, a rudimentary plant called the **Embryo** with an abundant supply of reserve food; the babyplant of the embryo is in a state of dormancy. Dormancy means the cessation of vital activities but alive. We have already seen that in a rudimentary plant, all the vegetative organs are represented. The leaves of the embryo are called the **cotyledons** or **seed-leaves.** According to the number of cotyledons, seeds are broadly divided into two main types *e.g.* Monocotyledons and Dicotyledons. Pea, Gram, Bean, Gourd, Castor oil seed, Mango, Tamarind and Pulses in general are examples of Dicotyledonous seeds while Maize, Paddy, Oat, Barley and other cereals, Bamboo, Grasses, Cocoanut etc. are monocotyledonous seeds. For the sake of convenience, the two main types are discussed separately.

Dicotyledonous Seeds—

For the purpose of examination of seeds, these should be thoroughly soaked in water for proper study. In describing a seed, the shape, colour of the testa, markings on the seedcoat or any other peculiarity may be noted down.

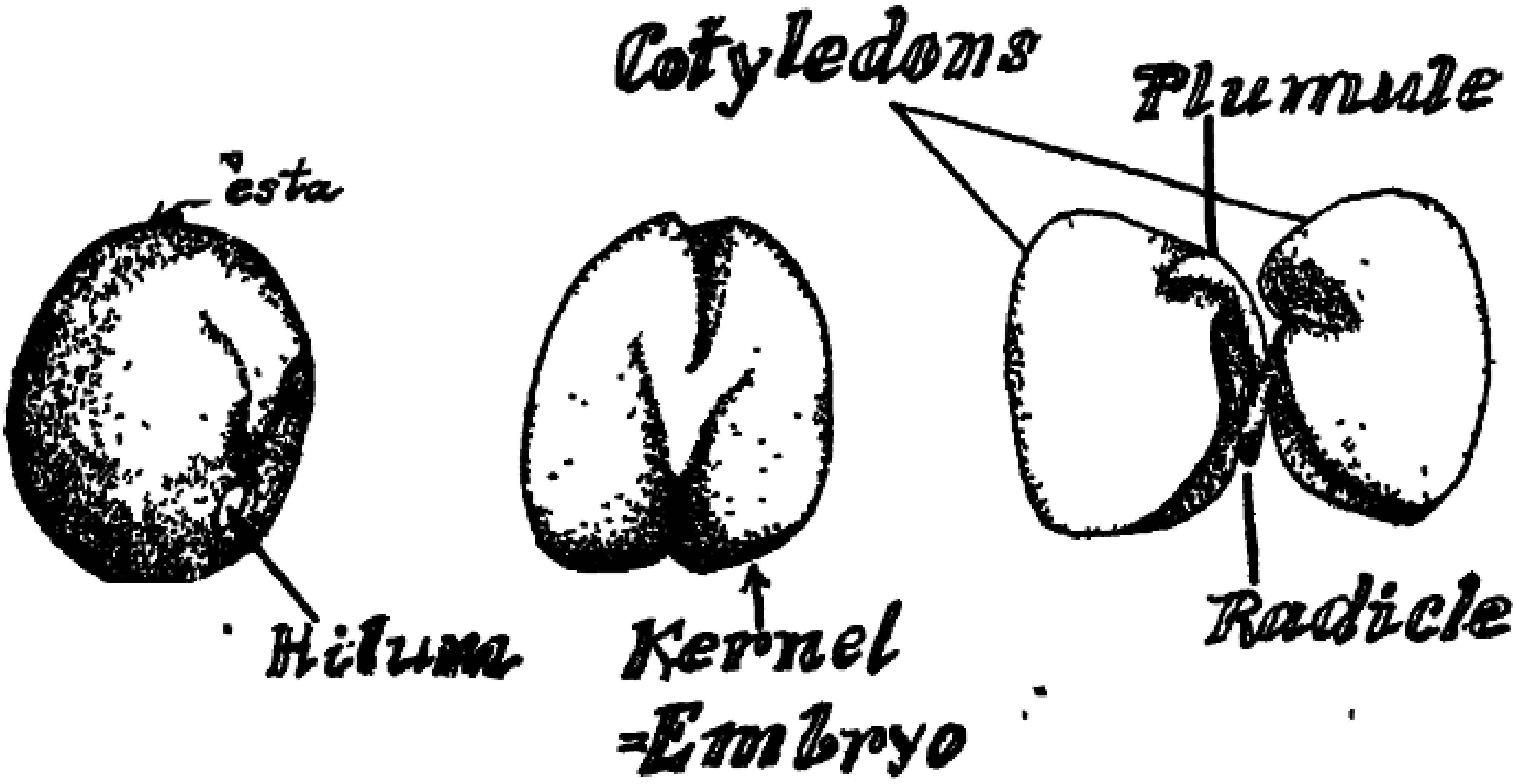
Every seed consists of a covering called the **Seedcoat** which encloses inside a fleshy substance called **Kernel.** The seedcoat is often differentiated into an outer covering called **Testa** which is thick, hard and resistive and an inner one called **Tegmen.** This Tegmen when present is thin and delicate and is either adpressed to the inner side of the testa or to the kernel. Somewhere on the testa, there is more or less, a prominent scar called the **Hilum,** which represents the place where the seed broke from the stalk (**funiculus**) by which it was attached to the wall of the fruit. Near about the hilum, there is a minute opening called the **Micropyle** through which in many cases water oozes out when a soaked seed is gently pressed. On removal of the seedcoats, the entire structure thus exposed is the **Kernel.** In case of Pea, Gram, Bean, Tamarind, Gourd and similar other seeds, when this kernel is gently pressed, it separates into two thick bodies called the **cotyledons** or seedleaves, which are attached laterally to a very short axis like a hinge. The region of attachment is called the **Nodal zone.** That end of the axis which is directed outward is known as the **Radicle** or future root while the opposite end which is placed in between the two cotyledons is the **Plumule** or future shoot. Thus all the organs of vegetation such as root, shoot and leaves are represented in the embryonic condition inside the seed to form the **embryo** or rudimentary plant. The cotyledons are fleshy owing to the deposition of food in them. When there is such a storage of food inside the cotyledons so that the kernel is equal to embryo, the seed is said to be **Exalbuminous** or **Non-endospermic** as there is no separate existence of food, (albumin or endosperm) outside the body of the embryo.

But in the case of castor oil seed, it will be noticed that food in the form of a separate foodbody (endosperm) is present outside the body of the embryo so that the kernel is equal to embryo plus endosperm. This type of seed is called **Albuminous or Endospermic.**

In Dicotyledonous seeds, the plumule is always the terminal member and the cotyledons are lateral members. The axis of the embryo has two more differentiated parts namely **hypocotyl** and **epicotyl.** The region which lies between the radicle and the nodal zone is the **hypocotyl** while that between the plumule and the nodal zone is **epicotyl.**

Brief description of a few seeds—

1. **Pea** (*Dicotyledonous, exalbuminous*)—Externally it is more or less rounded. Testa is present, and is semitransparent and resistive; testa showing micropyle and hilum which lie side by side; kernel is equal to embryo having two thick, fleshy cotyledons hinged



laterally to a short axis showing plumule and radicle at the extremities.

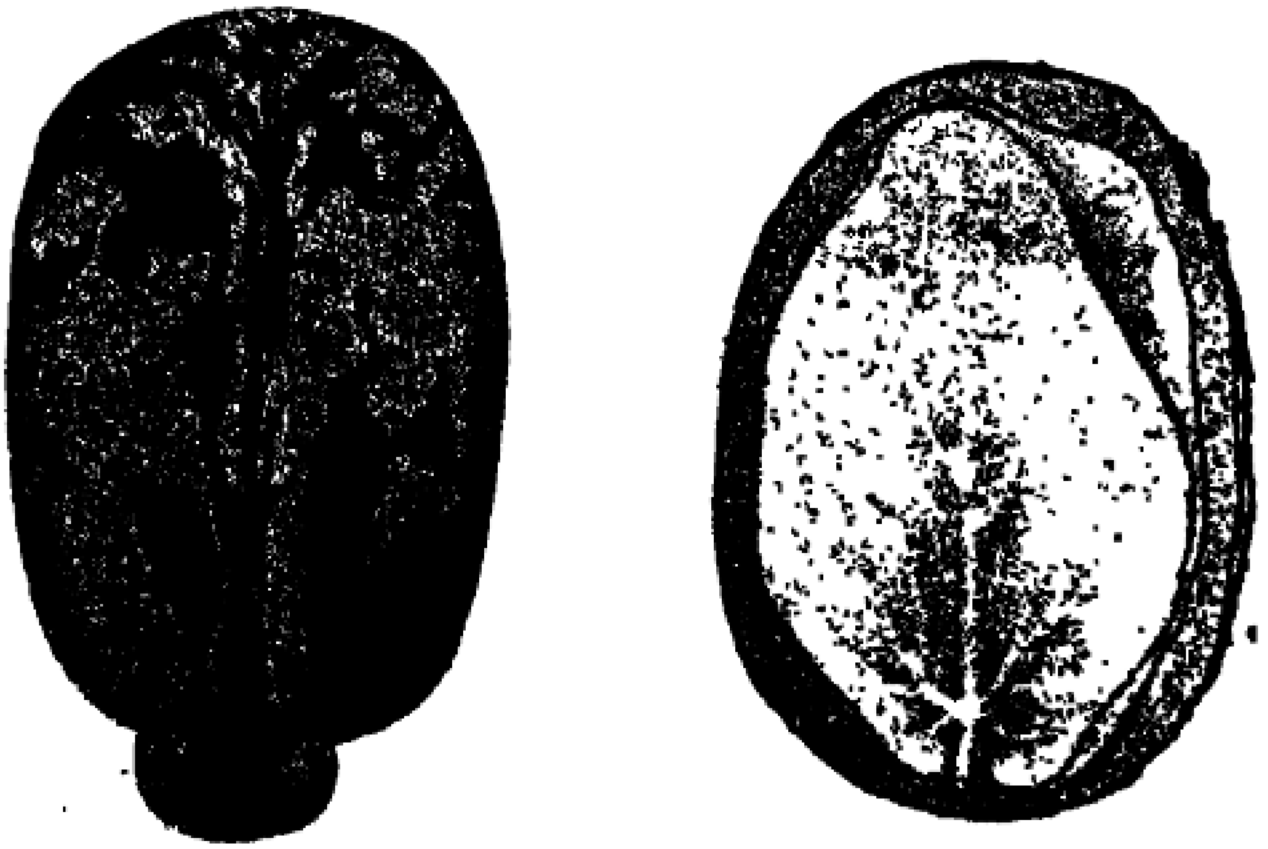
Structure of Pea seed:

Pea seed (Dicotyledonous, ex-albuminous)

- Seedcoat=*Testa* showing
  - Micropyle
  - Hilum
- *Kernel=Embryo*
  - Axis
    - Plumule
    - Radicle
  - Cotyledons (two, fleshy, lateral)

Castor oil seed—

Externally the seed is oblong in shape and consists of two seed-coats surrounding a massive **kernel.** The outer coat, testa is thick, hard, brittle and resistive with peculiar sculpturings on its dark, polished surface. At one end of the testa, micropyle and hilum are present no doubt but are usually hidden by a spongy swelling



Castor oil seed
C = Cotyledon

called the **caruncle** which is an outgrowth of the seed-coat near the hilum. On removal of the testa, the thin white papery tegmen is found to be closely enveloping the kernel. This kernel when carefully divided lengthwise (may be best done in boiled seeds) separates into two fleshy symmetrical halves which enclose an embryo. These two bodies together constitute the **Endosperm.** which completely surround the **embryo.** The embryo as usual consists of two lateral cotyledons and an axis showing plumule and radicle at the extrimities. The cotyledons, in this case, are thin and leaf-like and show venation because food has not been incorporated into them. The surface of the endosperm which lies in contact with the cotyledons, receives an impression of the veins of the cotyledons which is evident on removing the embryo.

Structure of Castoroil Seed:

- *Castoroil seed* (Dicotyledonous, albuminous)
  - —Seedcoats—
    - Outer=Testa showing hilum and micropyle covered by the caruncle.
    - Inner=Tegmen (adpressed to the Kernel)
  - —Kernel=
    - Foodbody =Endosperm containing the embryo inside.
    - Embryo
      - Axis—
        - Plumule,
        - Radicle.
      - Cotyledons (Two, thin, leafy, lateral showing veins)

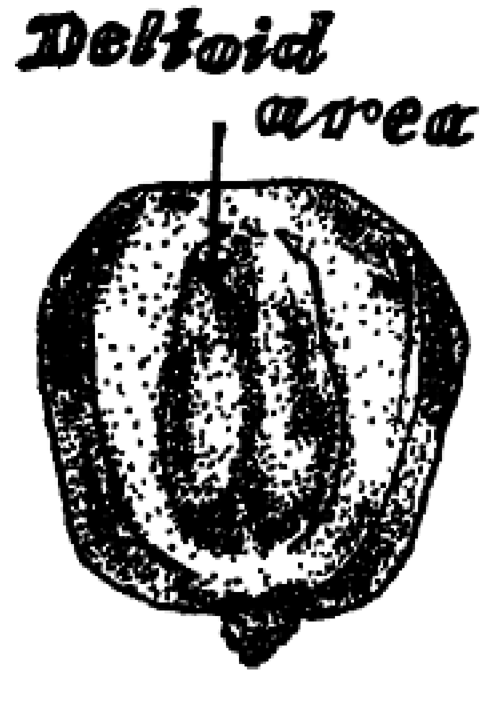
Monocotyledonous seeds—

Like the dicotyledons, the monocotyledonous seeds may be albuminous and exalbuminous but the former are more numerous and common than the latter. Examples of albuminous monocotyledonous seeds are Maize, Paddy, Barley, Wheat, Oat and other cereals, cocoanut, datepalm, grasses etc. While seeds of onion, Vallisneria etc. are exalbuminous in nature. Only the structure of the albuminous type will be discussed below.

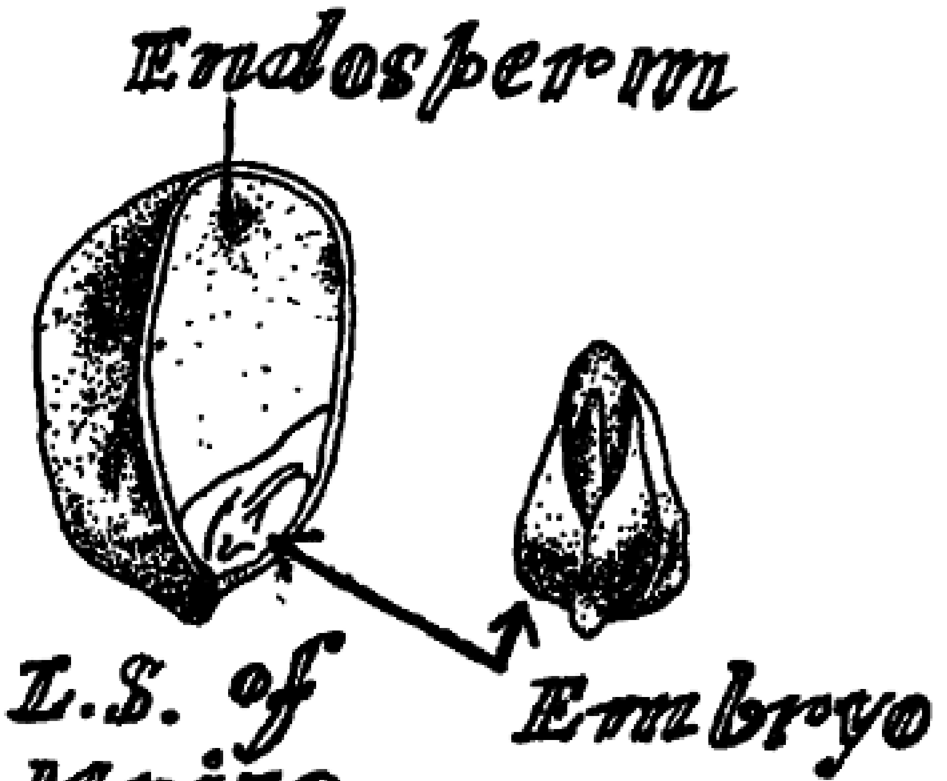
The so-called albuminous seeds of cereals and grasses are really fruits, each containing within it a tightly fitting seed inside. The wall of the seed (seedcoat) and the wall of the fruit (pericarp) are inseparably fused together to form a common covering which when removed exposes the kernel directly. Therefore the seed has got no separate existence from the fruit. The main bulk of the kernel in most cases, constitutes the endosperm commonly known as cereal grain in case of all cereals. Either at one side or at one corner of this endosperm, lies a minute embryo, the structure of which will be discussed in detail in the type described below. The cotyledon of grasses is very peculiar. It is known as the **scutellum.** It is shield-shaped and partially encloses the axis of the embryo and separating it from the adjoining endosperm. The back portion of the cotyledon which directly lies in contact with the endosperm is modified in such a way that it absorbs food from the endosperm with the help of enzymes secreted by it for the developing embryo when the necessity arises.

Description of an albuminous Monocotyledonous seed, Maize—

Each grain which is actually a fruit is more or less oblong in shape and flattened at both sides containing a tightly fitting seed inside at maturity. During development of the seed within the fruit, the seed consists of two coats but the outer one soon disappears and the inner one becomes firmly fused with the fruit wall or pericarp apparently forming a common wall. There is a deltoid area on one of the flattened sides of the grain which indicates the position of the embryo which may be seen through the semitransparent common wall. A longitudinal section of the fruit through the embryo shows the embryo embedded in a mass of endosperm together forming the **kernel.** The outermost part of the endosperm consists of a single layer of cells, the **aleurone layer** containing abundant aleurone grains, the remaining portion of it is well-differentiated into two distinct regions, an outer horny endosperm and inner starchy endosperm, the former containing more proteins than starch.



Maize.



L.S. of Maize.

(Between the common wall and the endosperm, another tissue, the **perisperm** may sometimes be present in some seeds which is the remnant of the nucellar tissue). The embryo consists of a single cotyledon, the scutellum which surrounds a very short axis. The cotyledon is a broad and flat absorbing organ lying in contact with the endosperm. The axis consists of plumule and very short hypocotyl and a radicle. The plumule has a growing stem-tip with a few rudimentary foliage leaves and is completely covered by a leaf-sheath called **coleoptile.** Similarly the radicle is also surrounded by a sheath called the root-sheath or **coleorhiza.**

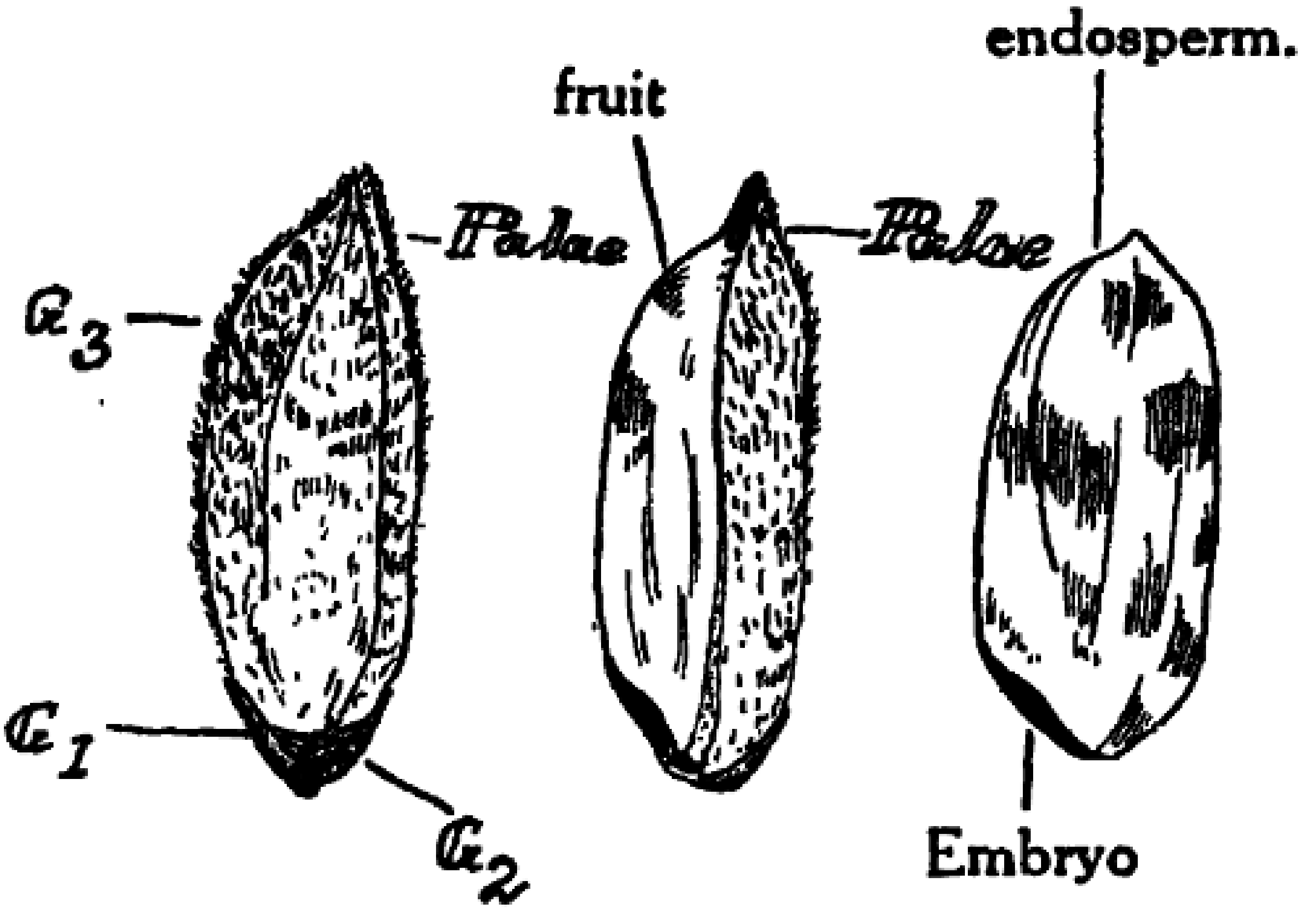
In general, it may be stated that the maize grain is a typical monocotyledonous type containing endosperm.

Structure of Maize grain :

- *Maize grain* (Really a fruit containing a tightly fitting monocotyledonous albuminous seed inside, which has no separate existence from the fruit).
  - Common wall (Pericarp and seed-coat inseparably fused together).
  - Kernel
    - Food body = Endosperm (main bulk) and Perisperm (rudiments)
    - Embryo
      - Cotyledon (one, terminal) or Scutellum
      - Axis
        - Plumule, covered by the coleoptile,
        - Radicle, covered by the coleorhiza.

Structure of Unhusked rice grain—

It is similar to Maize grain but the wall of the fruit is formed by three glumes and one palea. Its structure is shown in the following diagrams. G=Glume.



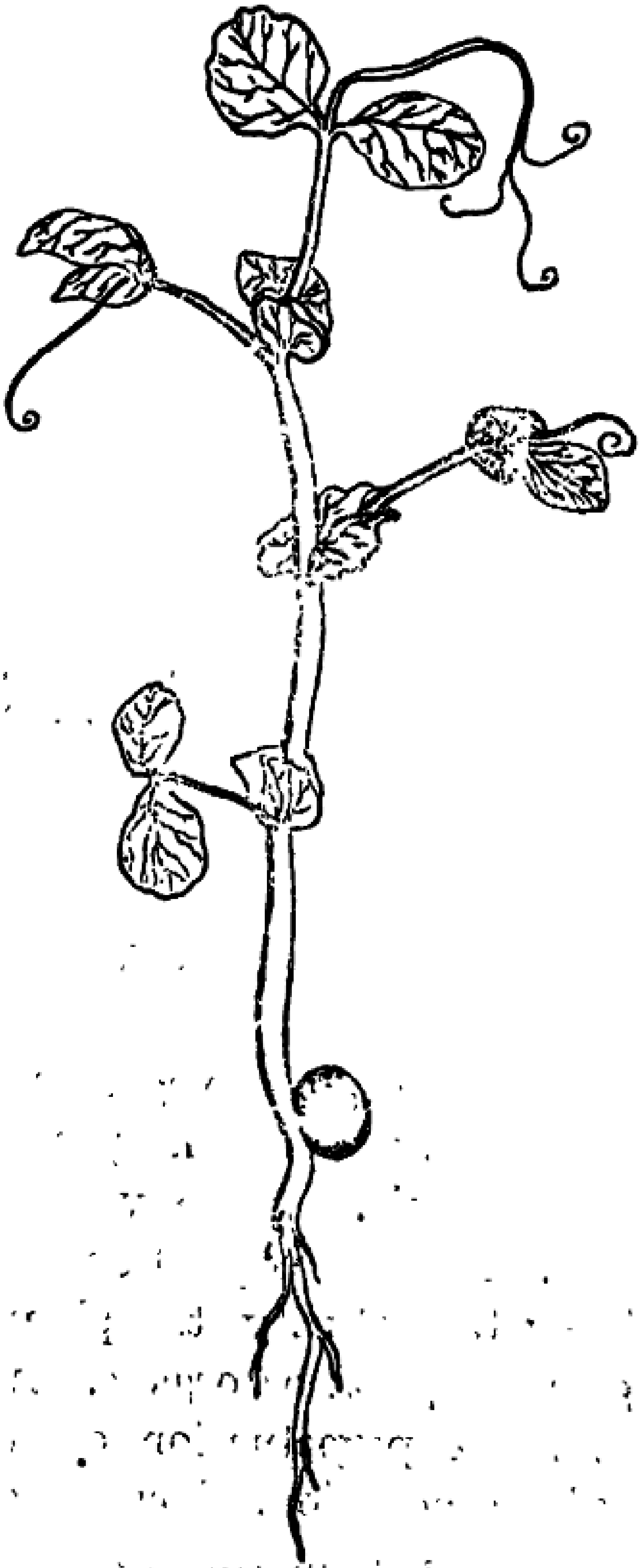
Parts of an angiospermic plant—

Normally the *vegetative body* of angiospermic plant consists of two main parts :—

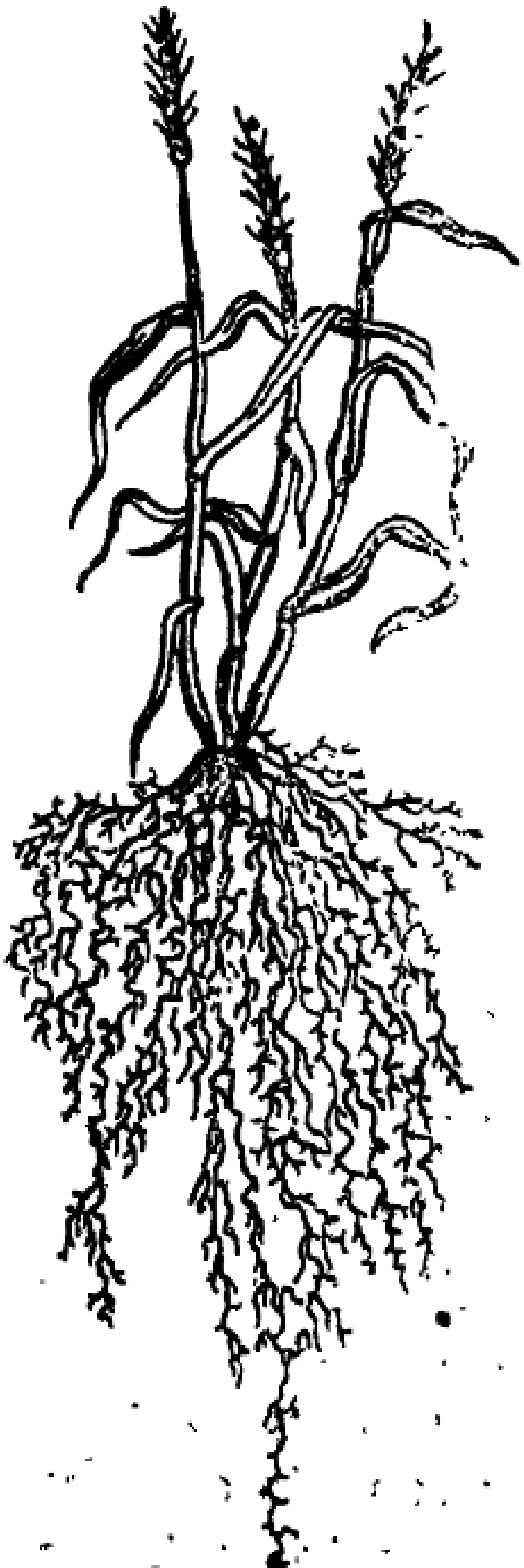
(1) An underground part—the **root-system** and

(2) A subaerial part—the shoot-system.

The root-system in dicotyledons consists of a main axis (**taproot**) from which secondary and tertiary branches (**rootlets**) originate in *acropetal order i.e.* the youngest branch is found towards the growing point. while the oldest branch is found farthest away from it while in monocotyledons there is no such taproot but a cluster of thread-like roots (**fibrous roots**) developed from the base of the stem. This rootsystem not only anchors the plants to the soil but also absorbs raw food-materials in solution from it for the plant. The shootsystem consists of a main axis called the **stem** which bears similar and dissimilar lateral members. The similar lateral members are the **branches** which often develop acropetally. The dissimilar lateral members are the



Seedling of pea showing taproot



Grass showing fibrous root.

leaves which develop from *definite regions* (**nodes**) of the axis or of its branches. The region between two successive nodes is called the **Internode.** Each leaf usually bears a bud in its **axil** (*i.e.* the angle made by the upper surface of the leaf with the stem) called **Axillary bud.**

The apex of each axis (stem or branch) is normally terminated by a bud called the **Apical** or **Terminal** bud. By the activity of the terminal bud, the stem elongates while by the activity of the axillary bud, the branch system is produced. The stem in case of trees, remains unbranched upto a certain height forming a **Trunk.** When the plant attains maturity, at proper seasons, it produces flowers and fruits in succession and within the latter seeds are produced. All these parts of plant have definite functions to perform and are spoken of as **organs.** The organs like roots, stems and leaves are concerned with the **vegetation** (*i.e.* growth from infancy to maturity) of the plant and are hence called **organs of vegetation.** Flowers, fruits and seeds are only produced at the time of its reproduction. Hence these are known as **organs of reproduction.**

Thus the plantbody consists of organs, vegetative and reproductive, because every living organism passes through two main phases in its life-cycle. One is vegetation, the other is reproduction. During vegetation *i.e.* growth of the plant from infancy to maturity, the plant-body consists of only the vegetative parts or organs. At maturity to make provision for the perpetuation of its race, it develops the organs of reproduction. Reproduction is again followed by vegetation and in this way the cycle of life is continued.

In seed—bearing plants, one notices that plants develop from seeds which when placed under favourable conditions develop into fully developed plants. Each seed contains within it a plant in a rudimentary state called Embryo where all the organs of vegetation such as roots, stems and leaves are represented in miniature forms. For this reason we begin our study from the study of **seeds.**

Seed germination—

It has already been pointed out that embryo lies within the seeds in a state of dormancy. When such a seed is placed under favourable conditions, the embryo wakes up and begins to grow until it establishes itself to the soil. The term seed germination includes all the stages from the time the dry seed is placed under those favourable conditions until it establishes itself to the soil forming a **Seedling.** This awakening of the embryo from inactive to active life and growth including a succession of changes is called seed germination.

Provided the seeds are viable and are placed on suitable substrata, the following essential conditions are necessary for successful germination. These are suitable **supply of water, supply of oxygen** and a **favourable temperature.** With a few exceptions *e.g.* Mistletoe and certain varieties of tobacco, light has got a retarding influence on germination at the primary stage. If any of the above conditions be absent, the seeds will not germinate.

Viablity or Vitality of seeds means its capacity to renew growth or germinate. This vitality also depends on longevity of the seed meaning the length of time a seed can remain dormant (which is very variable) and still be viable. The maximum longevity of seeds on record is that of Indian Lotus which can remain dormant but able to germinate even after 200 years.

1. **Water**—Water plays a most significant part during germination. It softens the seedcoats and thus helps the embryo to break through them easily. It swells the seeds, as a result the seedcoat bursts. It also facilitates the entrance of oxygen into the seed through the wet cell-walls. Water dilutes the protoplasm and helps it to perform its various functions actively. Finally the transfer of various foods is only made possible by the presence of water from the endosperm or the cotyledons to the growing regions of the germinating embryo for the building up of protoplasm. Too much or too little water prevents germination.

2. **Oxygen**—Every living organism requires suitable supply of oxygen for respiration in order to live. During germination, the growing embryos respire vigorously owing to the vigorous activities of the cells for which the supply of oxygen is necessary for normal germination.

3. **Temperature**—Favourable temperature is necessary for successful germination. For every type of seed, there are always maximum and minimum temperatures, above or below which germination will fail. There is also an optimum temperature when germination is at its best.

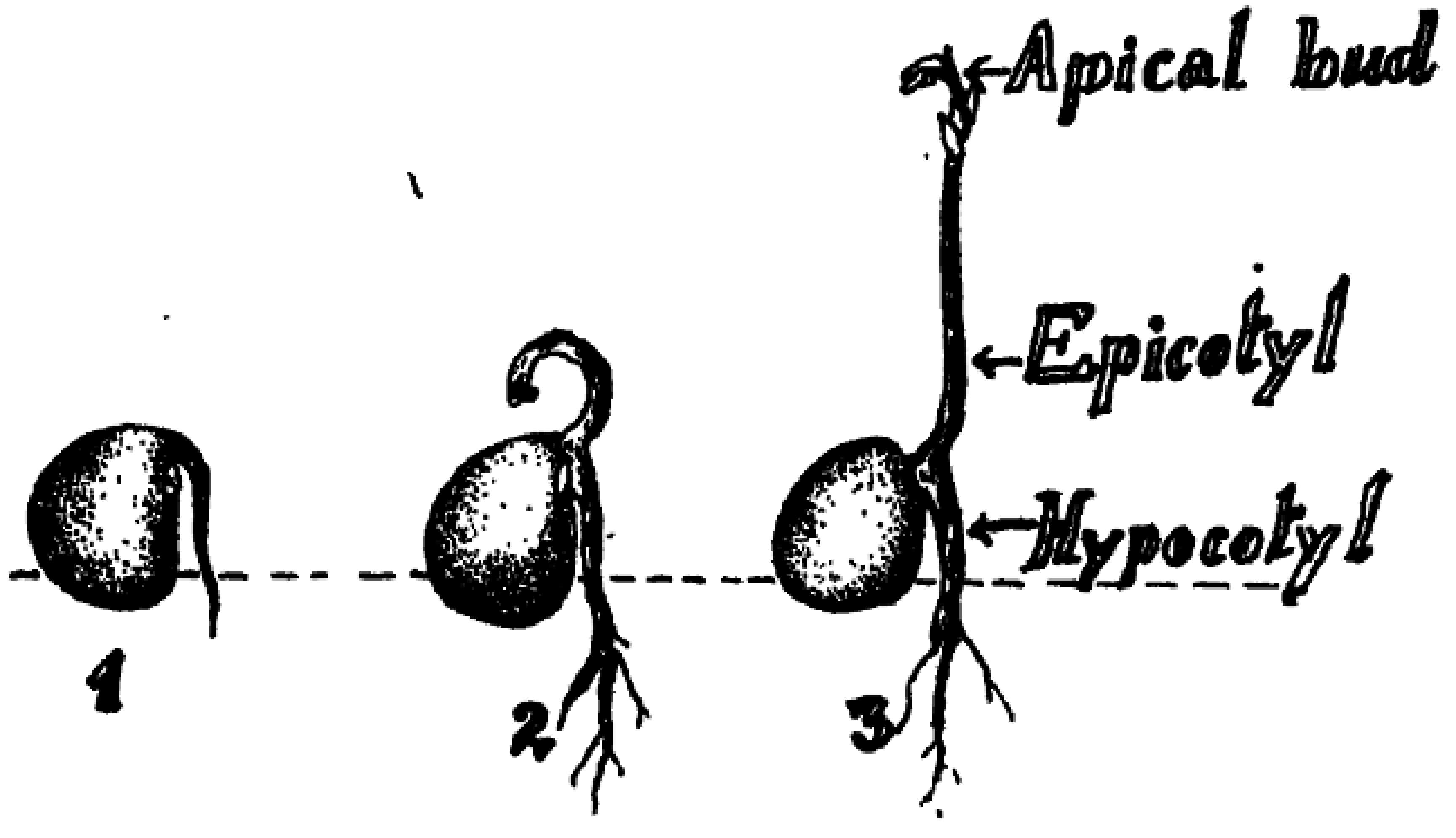
The essential nature of these conditions may be proved by the following experiments.

Seedlings—

There are two main types of germination—**Hypogeal or Hypogeous** and **Epigeal** or **Epigeous.** Both the above types are found in Dicotyledonous and Monocotyledonous seeds. Among the dicotyledons the seeds of **Pea, Gram, Mango** etc. have **hypogeal** whereas those of **Castor oil, Gourd, Tamarind** etc. have **Epigeal** types of germination. Among Monocotyledons, the germination is mostly hypogeal as in Maize, Rice, Wheat and other cereals though epigeal germination is not uncommon as in Onion. The germination of dicotyledonous and Monocotyledonous seeds will be discussed separately.

In Dicotyledonous Seeds—

Hypogeal germination.—This type of germination is typically exemplified by pea seed. After having been



Germination of Pea

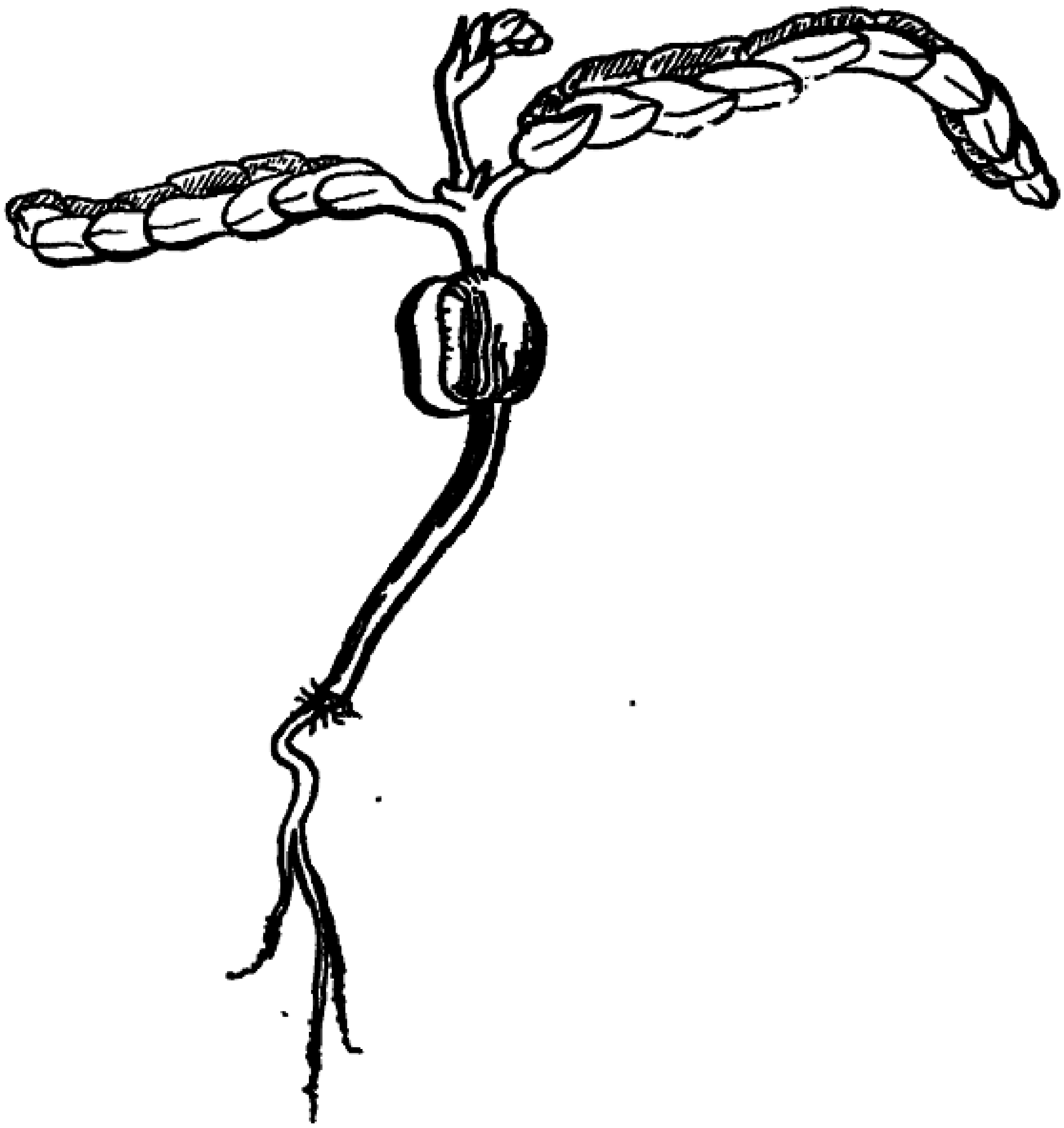
N.B.—For conditions of germination (Experiment), see Practical Biology.

placed under all the favourable conditions necessary for germination, the seed may start to germinate. There occur a series of changes preliminary to germination.

The seed imbibes sufficient quantity of water, resulting in the swelling of the seed and softening of the seed-coats. This initiates greatly increased physiological activities in the seed. By means of enzymes the stored foods inside the cotyledons are digested to some soluble and diffusible forms which can be easily assimilated directly by the active awakened embryo. Respiration is very marked at this stage and due to the presence of imbibed water, the protoplasm becomes more dilute to carry on renewed vital functions due to the transfer of digested foods to the growing regions of radicle and plumule, these organs now begin to grow. It is the radicle that usually starts its growth first and it is the first structure of the embryo that emerges out of the seed usually through the micropyle. This radicle then grows downwards into the soil forming an axis called the **Taproot** which in its turn produces secondary and tertiary branches in acropetal order, eventually producing the **root system.** In this way, the root system anchors the developing seedling to the soil. In such cases, the hypocotyl does not elongate. But during the development of the radicle due to the elongation of the epicotyl, the plumule is dragged out of the cotyledons in the form of a loop. The stalks of cotyledons also lengthen and help the plumule to emerge out of them. The plumule which is at first strongly hooked then straightens, out into the air and eventually forms the **Shootsystem.** The cotyledons being all along confined within the seedcoat, gradually shrivel up and ultimately die down when the seedling is completely established in the soil. *This type of germination is called hypogeal or hypogeous because the original position of the cotyledons is not disturbed at all, no matter whether the seed lies on the surface of the soil or inside the soil being all along confined within the seedcoat. In some cases, pea—seeds show epigeal type of germination (Priestley and Scott).*

Epigeal germination—

This type of germination is seen in Tamarind, Castor oil-seed etc. In this case also after the usual

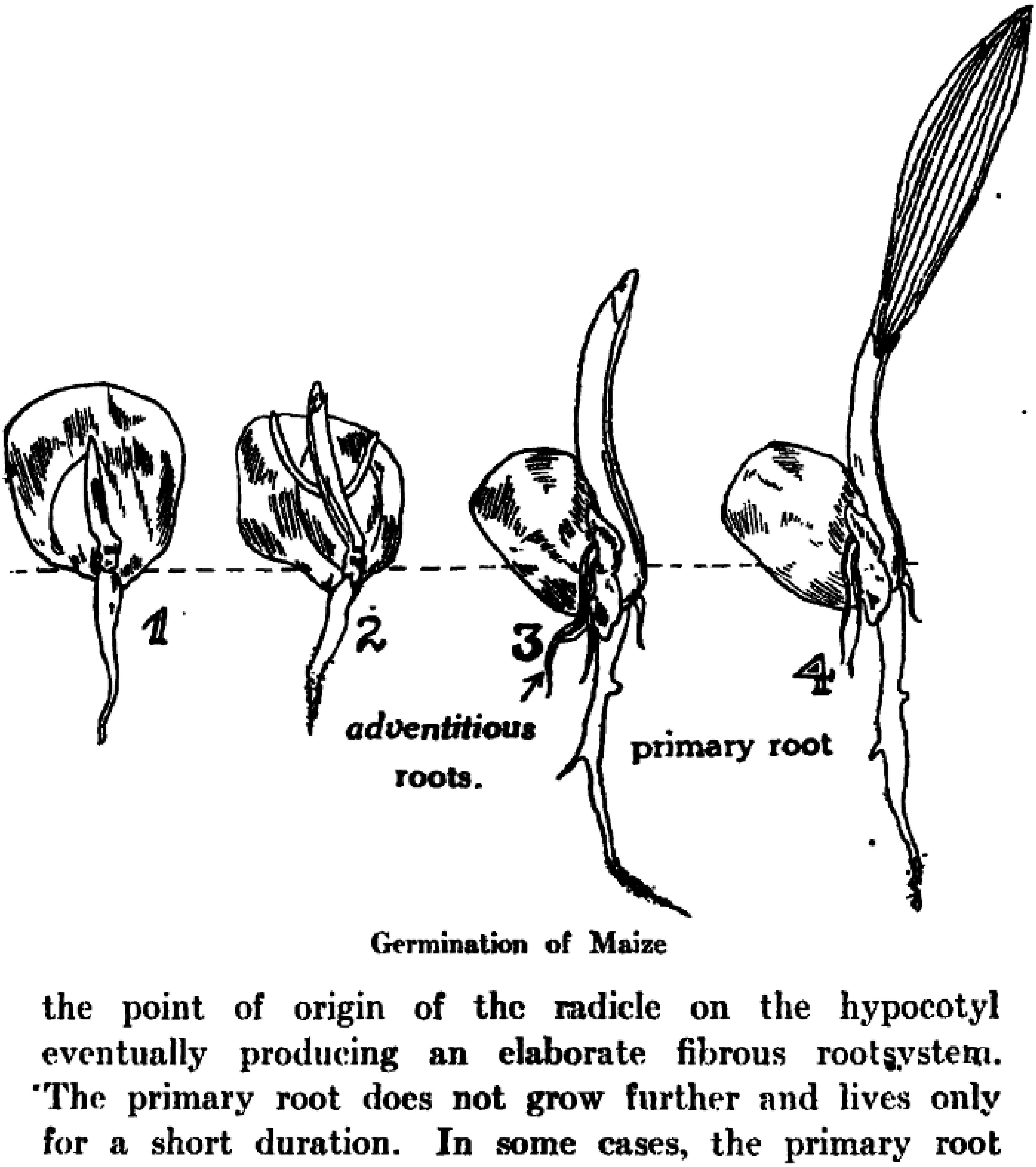


Tamarind Seedling

preliminaries, it is the radicle that comes out first and forms the rootsystem. During the development of the rootsystem, the hypocotyl begins to elongate vigorously as a result of which, the endosperm is carried up with the cotyledons from its original position. It has been pointed out that in this case, the cotyledons are relatively thin and at first act as absorbing organs Castor. The cotyledons, at first do not spread until the endosperm is almost entirely consumed. Finally, they separate and the remaining endosperm either dries up and falls off or their remnants adhere to the spreading cotyledons. The cotyledons now become green and function as first foliage leaves. The growth of the plumule is very slow in this case but ultimately it produces the shootsystem. The two cotyledons then dry up and fall away. *This type of germination is called epigeal because the original position of the cotyledons is disturbed, no matter whether the seed lies on the surface of the soil or inside the soil.*

In Monocotyledonous Seeds—

The germination of maize may be taken as typical of albuminous monocotyledonous seeds particularly the cereals and grasses. In such cases, the cotyledon or the scutellum which acts as an absorbing organ transfers food in digestible forms from the endosperm to the growing regions. As a result the plumule and the radicle begin to grow. As in pea, the hypocotyl does not elongate and the radicle is the first structure to come out but is followed almost immediately by the plumule. The radicle breaks through the coleorhiza and the common wall (fused pericarp and seedcoat) and forms a tiny primary root. Almost simultaneously with its development, adventitious roots begin to develop vigorously from



Germination of Maize

the point of origin of the radicle on the hypocotyl eventually producing an elaborate fibrous rootsystem. The primary root does not grow further and lives only for a short duration. In some cases, the primary root may last for several months. Later on, adventitious roots may also develop from the lower nodes of the axis of the shootsystem. The plumule surrounded by the coleoptyle, similarly emerges through the common wall and may often attain a length of ¾" to 1 inch, when the apex of the coleoptyle bursts (scott) and the first foliage leaf emerges. In this way, gradually the shootsystem is produced. After the establishment of the seedling in the soil, what is left of the seed gradually decays on the soil. *The germination is no doubt hypogeal, the cotyledon (scutellum) being all along enclosed within the common wall.*

Seeds and germination—

- **Dicotyledonous**
  - **Exalbuminous**
    - **Epigeal** *e.g.* Tamarind, Gourd
    - **Hypogeal** *e.g.* Pea, Gram
  - **Albuminous**
    - **Epigeal** *e.g.* Castor oil
    - **Hypogeal** *e.g.* Jack

- **Monocotyledonous**
  - **Exalbuminous**
    - **Epigeal** *e.g.* Water plantain
    - **Hypogeal** *e.g.* N. O. **Naiadaceae**
  - **Albuminous**
    - **Epigeal** *e.g. Onion*
    - **Hypogeal** *e.g. Maize*

CHAPTER XI

ROOTS

Distinguishing features—

Normal roots are derived from the direct downward prolongation of the radicle as in all dicotyledons at the time of germination of seeds but in some cases roots also arise from other parts of plants such as stems, leaves etc. and these are distinguished from the former as **adventitious roots.** Adventitious roots are characteristics of all monocotyledons though in dicotyledons they are not uncommon. Roots whether normal or adventitious in origin are typically underground structures and are distinguished from certain types of underground stems by certain characteristics. Roots usually grow downwards into the soil forming the descending axis of the plant avoiding light in search of water and food-materials from the substratum. Usually they are radially symmetrical and non-green. The body is not differentiated into nodes and internodes and do not bear leaves, leaf-buds and true reproductive structures, the flowers. In dicotyledons, the branches develop acropetally and these are endogenous in origin (*i.e.* structures originating deep in the tissue of the root). The tip of the root is protected by a cap-like structure called the **Root-cap,** a distinctive structure found on no other part of a plant.

Parts of a root—

Typically, the free ends (usually varying from 4 to 6 cm.) of the main axis (taproot) and of its main branches are called **root-tips.** Behind the root-tip in the older part of the root, growth in length never takes place and in this region that the secondary roots make their appearance. This region may be called the **Permanent region.** The root-tips when critically examined shows that it consists of four distinct regions beginning from the very end which are as follows :-

The root-cap region—

The apex of the root is protected by a tissue often of considerable thickness and is called **Root-cap.** In some cases as in Screwpine, it is **Multiple** or many layered being distinguished from the former which is **Simple** as in Banyan. The main function of the root-cap is **protection** of the delicate growing tip. The outermost part of the root-cap is slimy and mucilaginous for this reason, the passage of the root-tip is greatly facilitated through the soil. During growth of the root, the cap withers away no doubt but is replaced continuously by an active formative tissue within.

The region of cell-division—

The growing point which is completely protected by the root-cap is the region where active cell-division takes place forming new tissues.

The region of elongation—

Just behind the growing point, the newly formed cells which were in a state of division now begin to elongate and form the elongating region of the root. It is in this region that growth in length mainly takes place and the growing point with the root-cap is pushed through the soil.

The region of root-hairs—

Just behind the region of elongation, there is a region of the root varying in length where practically the growth in length has ceased and is densely covered by minute elongated unicellular hairs called the **root-hairs** by means of which the root absorbs raw food materials in watery solution from the soil. It is in this region only that the actual absorption of nutritive material is confined. These hairs also firmly adhere to the soil particles thus giving additional anchorage of the root to the soil. The root-hairs develop superficially *i.e.* are **exogenous** in origin. As the root elongates, new root-hairs develop towards the elongating region and the old ones gradually die down.

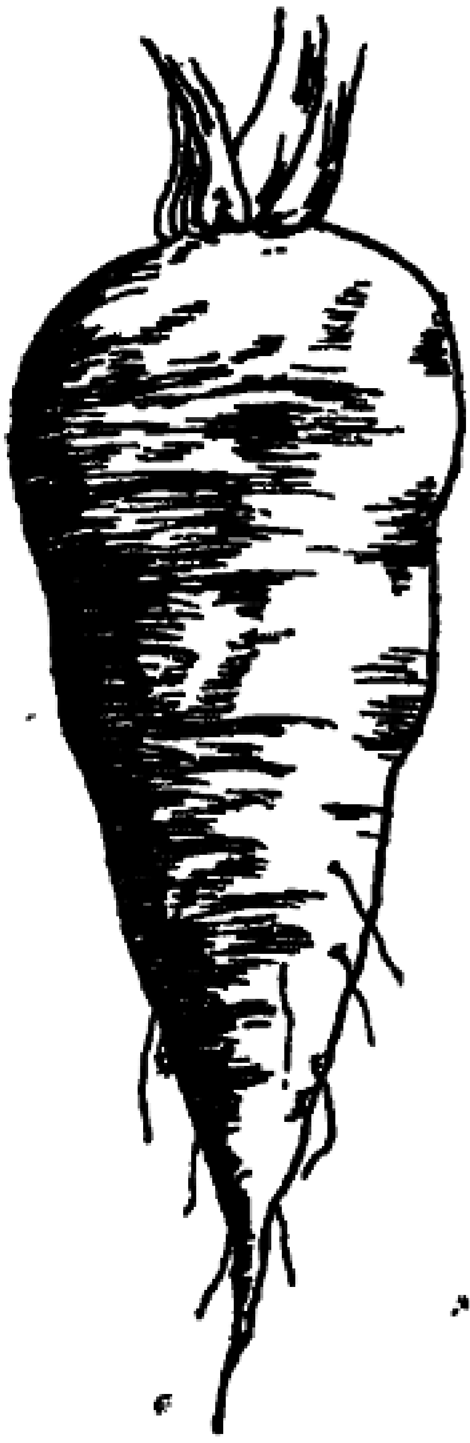
The above four regions together constitute the **root-tip.** The root-hair region is also called the *region of maturation* because various internal tissues and conducting channels are gradually differentiated.

The permanent region—

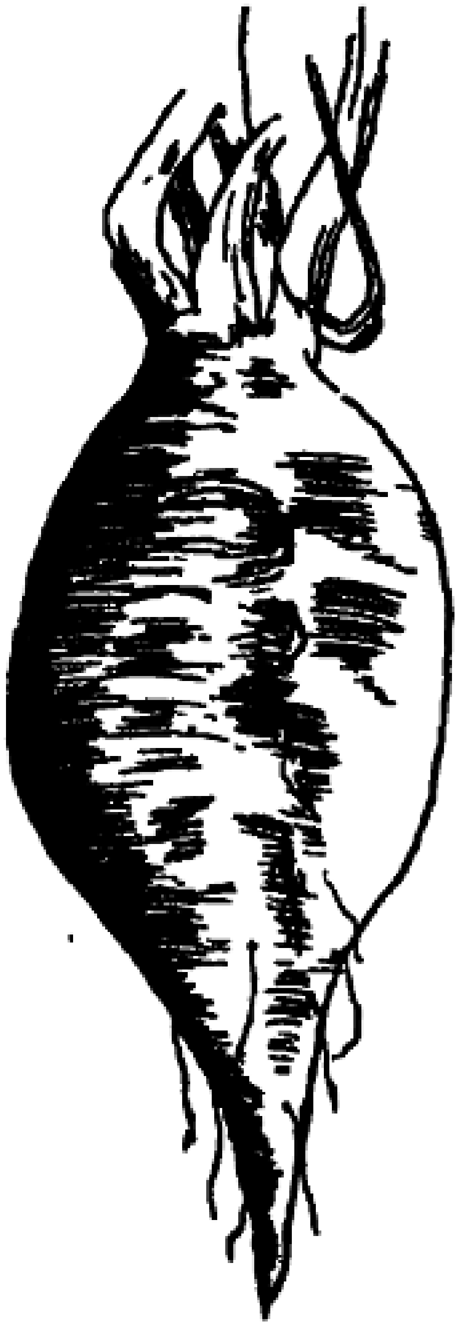
Behind the root-tip the main bulk of the root bearing the secondary branches is called the permanent region which is mainly concerned with the conduction of raw-food materials in watery solution already absorbed by the root-hairs from the roots, up the stem to the leaves for elaboration.

Kinds of roots—

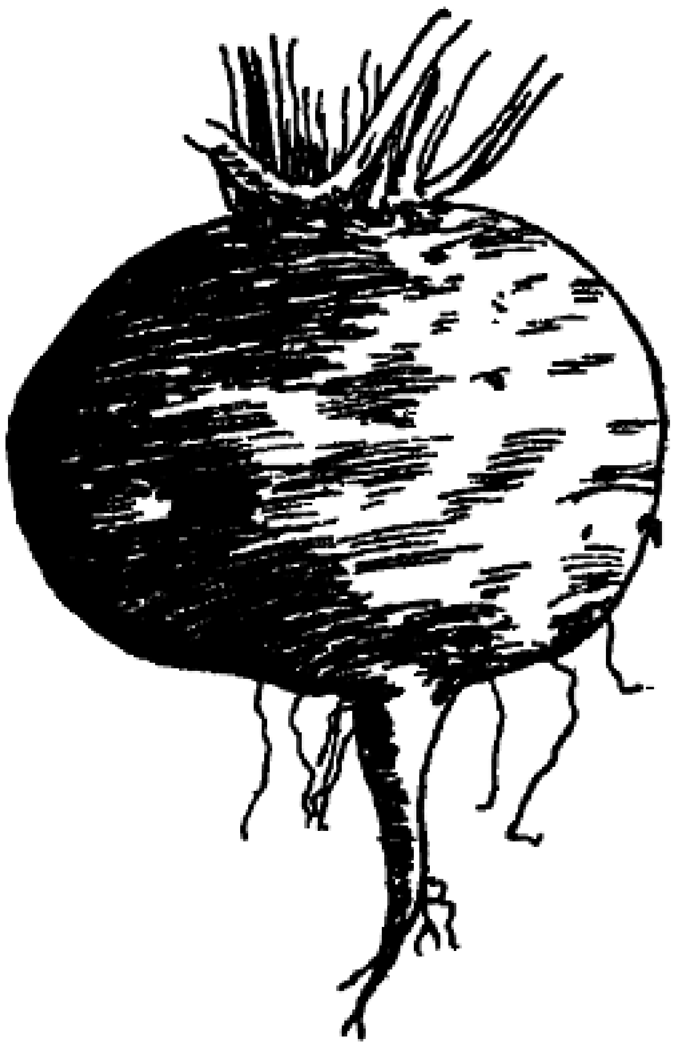
Roots according to their origin are of two types namely **Normal** and **Adventitious** which have already been dealt with. The taproot of all dicotyledons is **normal root** and is called **Primary.** It produces **secondary** and **tertiary** branches in acropetal succession. The taproot with its branches forms the normal or taproot system. All other roots are **adventitious.** The *fibrous rootsystem* of monocotyledons is the typical example of such roots.



Conical



Fusiform



Napiform

Sometimes roots whether normal or adventitious undergo **modifications** in response to varied requirements. Thus for the purpose of storage, taproots become very much swollen and assume various forms. It may be

fusiform *i.e.* broadest in the middle with the two ends tapering like a spindle as in Radish; **Napiform** *i.e.* very much swollen in the middle but abruptly tapers towards the apex as in Beet, Turnip etc. and **Conical** when it is broadest towards the base and gradually tapers like a cone towards the lower end *i.e.* apex as in carrot. (Excepting the carrot, the various examples which are cited are in reality in case of turnip—swollen hypocotyl, in Beet—swollen root and hypocotyl and in case of radish—sowllen hypocotyl and base of leafy stem—Priestley and Scott.

Rarely however as in Ruellia tuberosa, the secondary branches of the primary rootsystem become swollen and **tuberous.** All these roots are collectively called **storage roots.** Similarly **adventitious roots** also undergo modifications to meet various requirements of plants. These modifications are due either *to meet special mechanical or special physiological functions* and the important types are described below :

Chief types of *modified adventitious roots performing special mechanical functions are* : **Prop roots, Stilt roots** and **Climbing roots.**

Proproots—In order to give additional support to large horizontal branches as in Banyan, adventitious roots originate from these branches which are at first aerial but subsequently grow vertically downwards and on reaching the ground fix themselves to the soil. These ultimately become thick and woody and thus act as *pillars* supporting the horizontal branches. These supporting roots when young are non-green.

Stilt roots—In many plants growing usually in swampy situations as in Screwpine, stout adventitious roots develop from the trunk and these grow obliquely downwards and finally by fixing themselves to the soil give additional anchorage to the plant.

Climbing roots—The climbing roots of such plants as Scindapsus officinalis (Gajpipul), Piper (Gachpan) are also a form of adventitious roots. Large number of these roots are usually produced on the sides of the stem from nodes and internodes growing along the surface of another plant or other suitable objects where they radiate and flatten out and hold the stem firmly to the surface. In Scindapsus (Gajpipul), these often become very long and often grow around the support forming an intricate network.

The various *modified adventitious roots performing special physiological functions* are as follows:

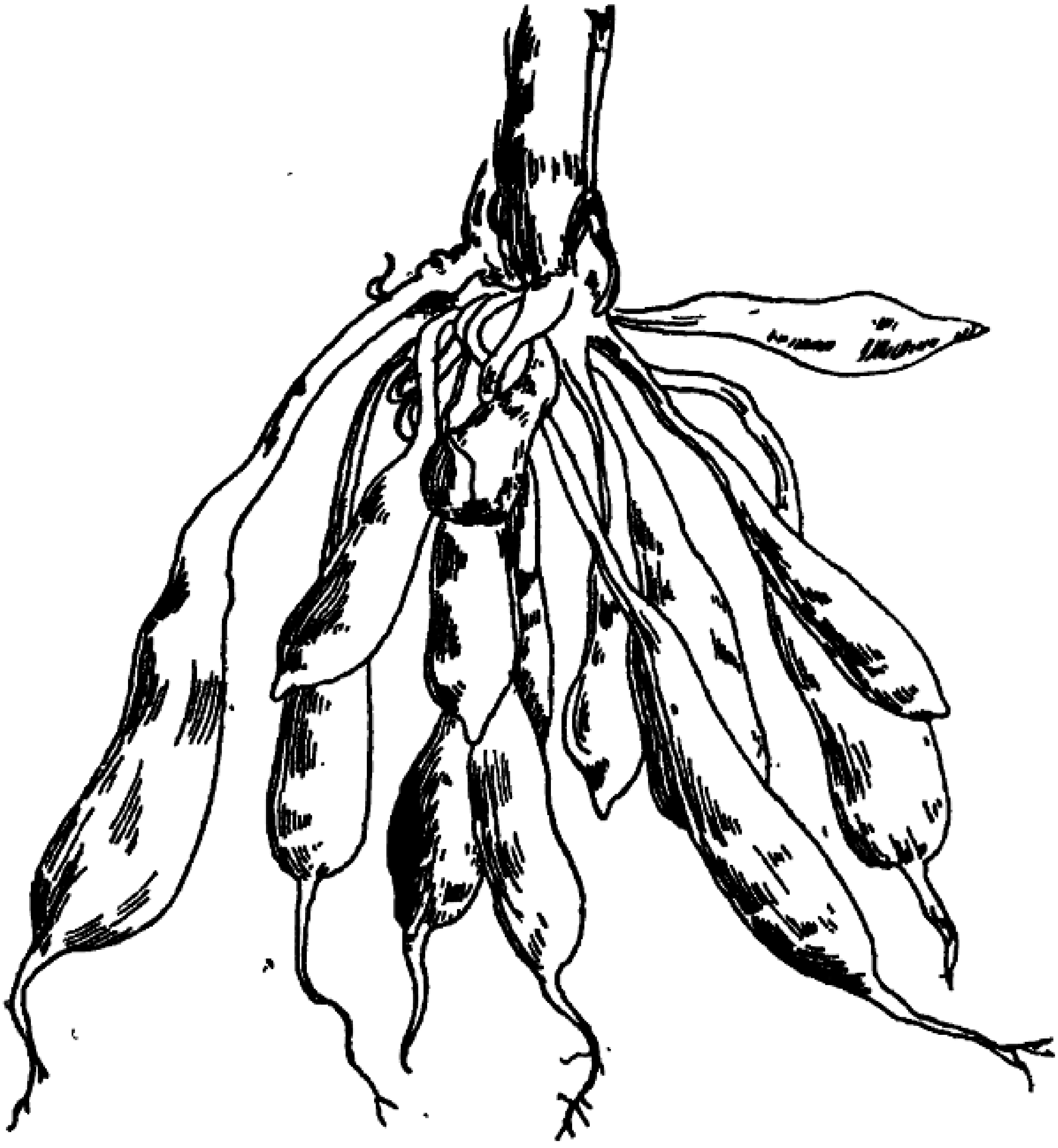
Storage roots—The storage is a normal function but sometimes it has carried it to such a degree as to completely modify the ordinary forms. Like the modifications of taproot for storage, several types of adventitious storage roots are recognised such as **Tuberous, Fasciculated, Nodulose etc.** When tuberous, some of the adventitious roots become swollen and fleshy like tubers as in sweetpotato (Rungaloo) where these roots usually develop from the nodes along with other fibrous roots. When all the fibrous roots become swollen and fleshy so that they seem to arise from a common point from the base of the stem giving rise to a cluster of fleshy roots, the roots become *fasciculated* as are exemplified in Asparagus (Satamooli).

Examples of *nodulose* roots are rare but are found in costus species and sometimes in Curcuma (Amada). In such roots only the apical portion of adventitious roots suddenly becomes swollen.

Tuberous roots of sweetpotato

Pneumatophores—Plants inhabiting swampy situation where the soil is waterlogged and poor in oxygen-content, develop special roots from underground parts which grow vertically upwards into the air for maintaining the gaseous interchange between the plant and the atmosphere. There are minute openings usually on the surface of these roots, through which the plant respires. Such *breathing roots or pneumatophores* are commonly found in Heritiera (Sundri). Rhizophora, Jussiaea (Keshardam).

Epiphytic roots—These are hanging aerial roots which are characteristic of *epiphytes* such as orchids. These are not positively geotropic *i.e.* do not grow vertically downwards like the aerial roots of banyan and are usually green towards the tip. Such roots develop special structures called *Velamen* on their surface for absorption of atmospheric water.



Fasciculated roots of Asparagus

Haustoria—These are highly modified types of adventitious roots for absorbing prepared foods from other plants and are found in some parasitic seed-plants such as the common Dodder, Mistletoe, Loranthus, Orobanche etc. The common dodder is a parasitic twiner devoid of foliage leaves which twines round suitable plants called hosts and sends out short roots into the stem of the host plant wherever the parasite comes in contact with it. Such roots are called *Haustoria* or *parasitic roots* which on penetrating the host plants establish connection with their food-conducting channels robbing them of the prepared food and often killing them by this method.

Assimilatory roots—In Tinospora (Goloncho) long, hanging aerial adventitious roots develop which are green in colour. Due to the presence of the green pigment, the chlorophyll, these roots can prepare organic foods in the presence of sunlight from formative materials. Such roots are called *Assimilatory roots* which are concerned with the process of assimilation.

Functions of roots—

Normal functions of roots whether normal or adventitious are :—

1. **Anchorage**—*i.e.* fixation of the plant to the soil (environment) which is a *mechanical function.*
2. **Absorption and conduction**—Raw food materials which are absorbed in watery solution by the root-hairs are conducted through the root to the stem.

3. **Storage**—Roots also store up sufficient quantity of food and water in them for future use of the plant.

Functions of absorption, conduction and storage together constitute the *physiological functions of the root.* Besides these normal functions roots also carry on special mechanical and special physiological functions which are as follows :—

Special mechanical functions

1. Additional support as in the case of prop roots of banyan.
2. Additional anchorage as in the stilt roots of screwpine.
3. Climbing roots of Scindapsus (Gajpipul).

Special physiological functions

1. Storage as in the fleshy roots of sweetpotato.
2. Breathing as in the pneumatophores of Heritiera (Sundri).
3. Absorption of moisture from the atmosphere as in the epiphytic roots of orchid.
4. Absorption of prepared food from other plants as in the haustoria of dodder.
5. Assimilation as in the assimilatory roots of Tinospora cordifolia.
6. Vegetative propagation—This function is performed by the roots of Trichosanthes (Patal). Many roses, Black-berries and similar other plants are often propagated by root-cuttings.

Roots

- **Normal**
  - **Ordinary forms**
    - **Taproot system**
      e.g. In dicotyledons.
  - **Modified forms**
    Storage roots
    - Fusiform
      e.g. Radish
    - Napiform
      e.g. Beet.
    - Conical
      e.g. Carrot
    - Tuberous
      (Branches)
      e.g. Ruellia
- **Adventitious**
  - **Ordinary form**
    - Fibrous root system
      e.g. In monocotyledons
  - **Modified forms**
    - Performing
      Special mechanical
      function
      - Prop-roots
        e.g. Banyan
      - Stilt-roots
        e.g. Screwpine
      - Climbing-roots
        e.g. Gajpipul
    - Performing
      Special physio-
      logical function
      - Storage-roots
        - (*a*) Tuberous
          e.g. Sweet-potato
        - (*b*) Fasciculated
          e.g. Asparagus
        - (*c*) Nodulose
          e.g. Amada
      - Pneumatophores
        e.g. Sundri.
      - Aerial roots
        e.g. Orchid.
      - Haustoria
        e.g. Dodder
      - Assimilatory
        e.g.. Tinospora

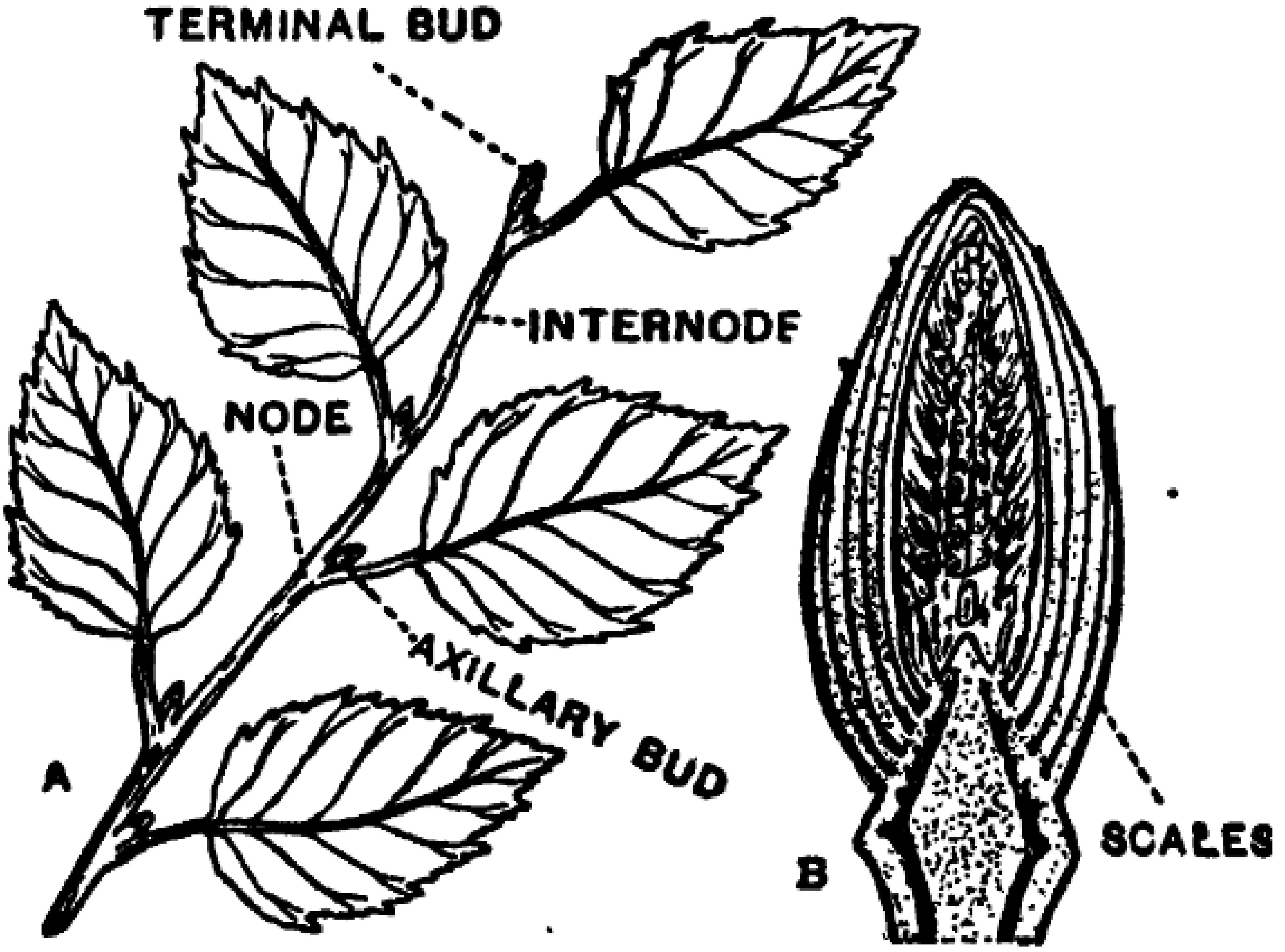
Function of Roots

- **Normal**
  - **Mechanical function i.e. fixation**
  - **Physiological**
    - (a) Absorption,
    - (b) Storage
- **Special**
  - **Special mechanical functions**
    - Additional support *e.g.* Prop roots of banyan
    - Additional anchorage *e.g.* Stilt roots of screwpine
    - Climbing *e.g.* climbing roots of Gachpan, Gajpipul
  - **Special physiological functions**
    - Storage *e.g.* swollen tap-roots and fleshy adven. roots.
    - Breathing *e.g.* Pneumatophores of Sundri.
    - Absorption of moisture from air *e.g.* aerial roots of orchid.
    - Absorption of prepared food of other plants *e.g.* Haustoria of dodder.
    - Assimilation *e.g.* Green aerial roots of Tinospora
    - Propagation *e.g.* Waterhyacinth, roots of Patal,

CHAPTER XII

THE SHOOT

The structure developing from the plumule with axis, branches, leaves and flowers goes by the name of **shoot.** The main axis is the stem which gradually branches in acropetal succession. The stem has the tendency to grow upwards and to bear dissimilar organs like the leaves. The development and healthy growth of the leaves are dependent on sunlight therefore the stem seeks light.



Shoot

Longitudinal section of bud

The stem bears at its ultimate apex, a much compressed leafy structure which is called a **Bud.** The similar members developing on the stem *i.e.* the branches arise from the superficial tissue of the main stem. The position from which the leaves arise is called the **Node.** The branches arise from an **angular** position made by the leaves with the main stem. The upper angle made by the leaf with the stem is the **AXIL.** The axil is the most important position because buds arise from it and develop into branches. The space which is free from any leafy structure on the stem between two successive nodes is called the **Internode.** Sometimes the *internodes* are suppressed and the leaves seem to arise from the same position as in **Pineapple** (Anaras). This is the ***Rosette*** type.

Distinction between a root and a shoot.

	Root.		**Shoot.**
1.	The root arises from the radicle.	1.	The shoot arises from the plumule
2.	The root avoids light.	2.	The shoot seeks light.
3.	The root is the descending axis.	3.	The shot is the ascending axis.
4.	Root bears organs like itself *e.g.* branches.	4.	The shoot bears both similar and dissimilar organs *e.g.* branches and leaves.
5.	The apex of the root has a rootcap.	5.	The apex generally terminates in a bud.
6.	There is no node or internode.	6.	There are nodes and internodes.
7.	There is absence of green colour.	7.	Green colour is invariably present.
8.	Branches are endogenous in origin.	8.	Branches and leaves are exogenous in origin.

Functions of the stem :—

(1) The food material in solution goes up from the root to the leaves through the stem.

(2) The manufactured food from the leaves is transferred to different parts through the stem.

(3) It sometimes acts as a reservoir of reserve material for future use.

(4) It bears leaves, branches and flowers to their advantage.

Forms of Stems—

Stems are generally *round* as in the majority of plants. Sometimes they are *triangular* as Cyperus rotundus (Mootha) or square as in Ocimum sanctum (Toolsy) or *flattened* as in Opuntia (Phanimonsa).

A classification of plants is often made according to the nature of the stem *e.g.* **Herbs, Shrubs** and **Trees.**

Herbs—These are soft and delicate plants and are characterised by the absence of the thickening and hardening of tissues. They are again subdivided into three kinds *e.g.* *Annual, Biennial* and *Perennial.*

Annual—These plants complete their lives in one season only *e.g.* wheat, rice etc.

Biennial—These plants complete their life-cycles in two seasons. In the first season, they grow and store up reserve food matter for the next season which is primarily meant for flowering and fruiting. The Biennials are often cut short in the duration of their life-cycles and become annuals *e.g.* Radish (Moola), Cabbage, Beet.

Perennial—These plants live for more than two seasons *e.g.* Plantain, Ginger, Canna.

Shrubs—The plants are not very large but they are characterised by hard and woody stems and a number of equally developing stems arise from the level of the soil as Rose, Chinese Rose (Jaba), Croton, Cotton.

Trees—These plants have main axes next to the soil which are known as Trunks and are considerable in bulk and are hard and woody, *e.g.* Mango (Am), Teak, Rose-apple (Golap-jam).

Modifications of the Stem—

I. Underground stems or subterranean forms.

Stems are generally found above the ground but are often underground or subterranean, the usual green colour is absent, the leaves are replaced by scale leaves and often they become reservoirs of reserve materials. They are commonly mistaken for roots but are characterised by having structures similar to stems, bear scale leaves and are often divided into nodes and inter-nodes. The underground stems perform the following functions:—

(1) They store up reserve food,

(2) They help in perennation *i.e.* allow the plant to tide over a period of bad weather conditions,

(3) They help in propagation of plants.

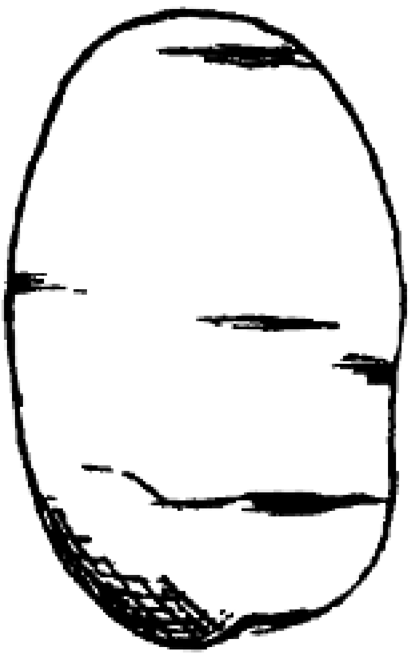
The common forms of underground stems are:—

(1) *Rhizome,* a fleshy stem occurring under the soil. It is divided into nodes and inter-nodes. It bears scale leaves from the axils of which annually leafy shoots arise. It grows at one end and dies at another *e.g.* Turmeric,

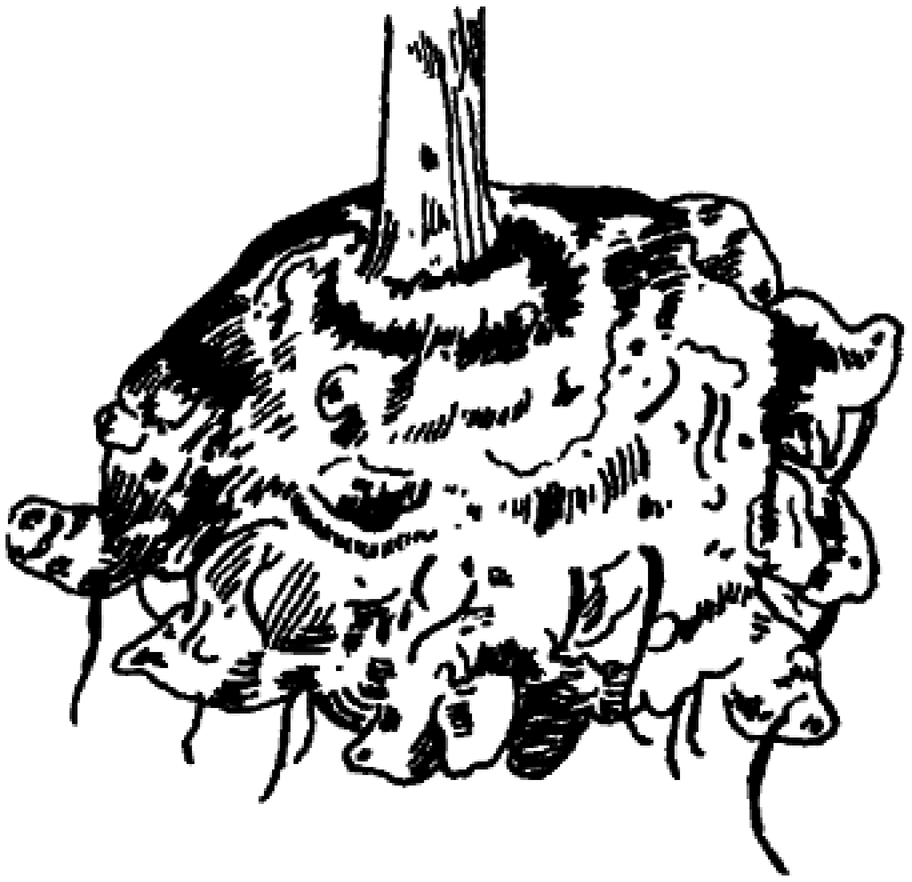
Ginger etc. Sometimes the rhizome is vertical and is called Rootstock as Alocasia (Mankachu).

Rhizome of ginger

(2) *Tuber,* this is the form of underground stem which becomes swollen with the accumulation of starchy food material. There are scales on a tuber with buds which are known as eyes *e.g.* Potato.



Tuber of Potato

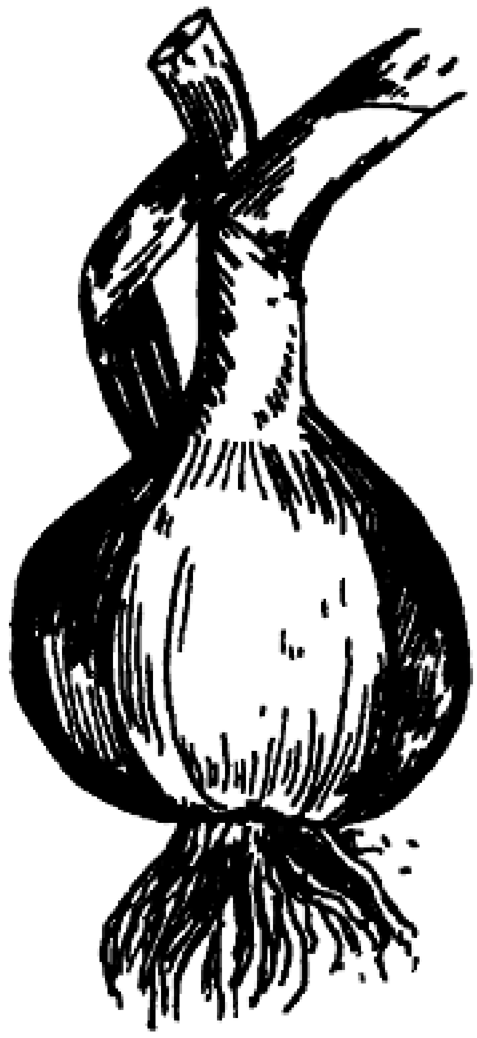


Corm of 'Ol'

(3) *Corm,* this form of underground stem is much swollen and bears a number of thick leaves on the top.

The corm bears a large number of roots and a number of buds on its sides *e.g.* Amorphophallus (Ol), Kohl-rabi or Ol-kapi, Saffron (Jafran).

(4) *Bulb*, this form has a small disc bearing a number of closely packed leaves. The leaves are fleshy and store up reserve food materials *e.g.* Onion (Pianj), Garlic, Lily.



Bulb of onion

Bulbs are of two types *e.g.* Tunicated and Naked. Tunicated bulbs have fleshy scales enclosing one another in concentric manner and covered externally by dry scales as in Onion, Garlic while the naked bulb has fleshy scales but not covered externally by dry scales as in Lily.

The underground stems have the following special features :—

(*a*) They often bear scale leaves.

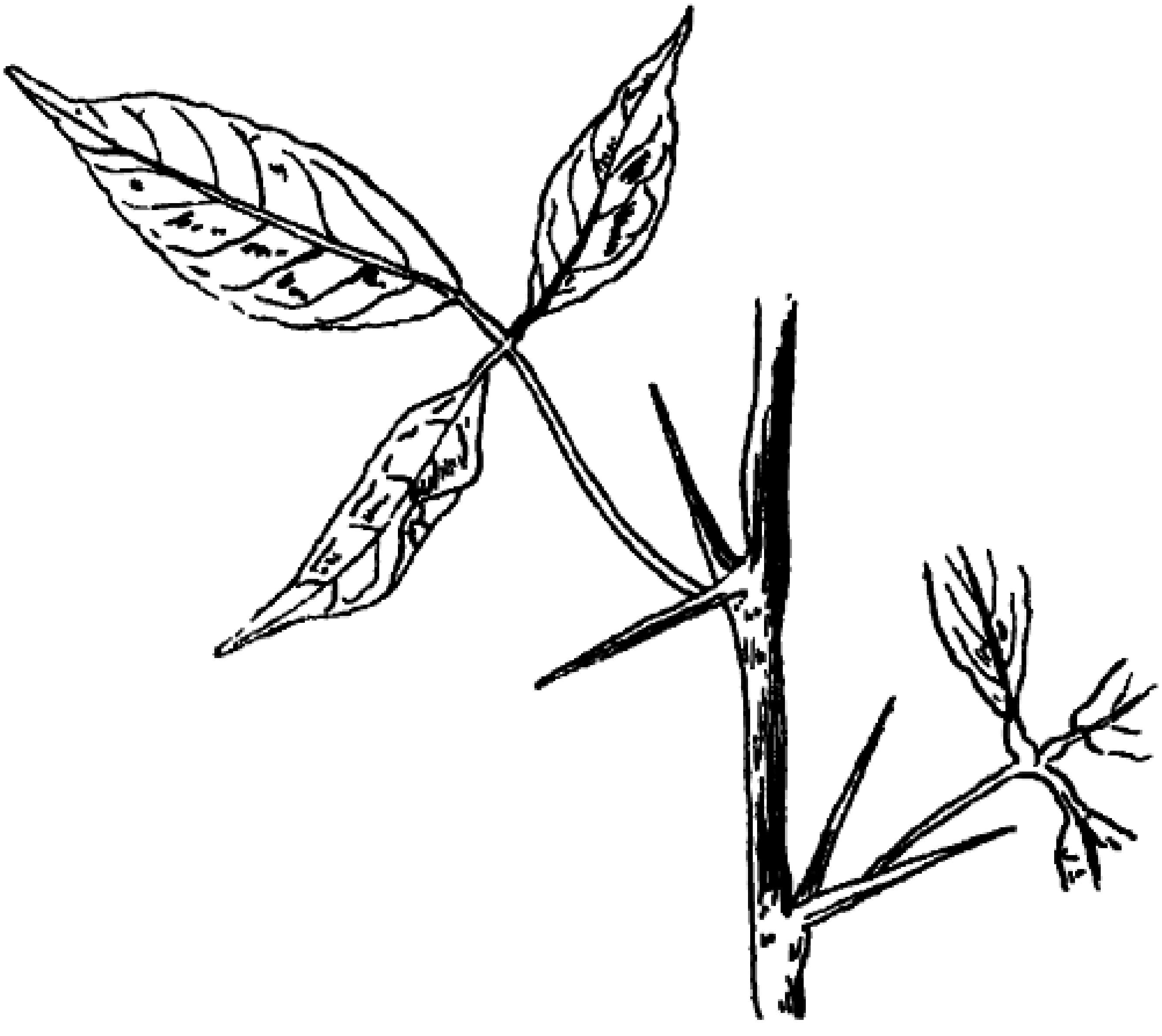
(*b*) They store up reserve food.

(*c*) They are often divided into nodes and internodes.

(*d*) They bear buds.

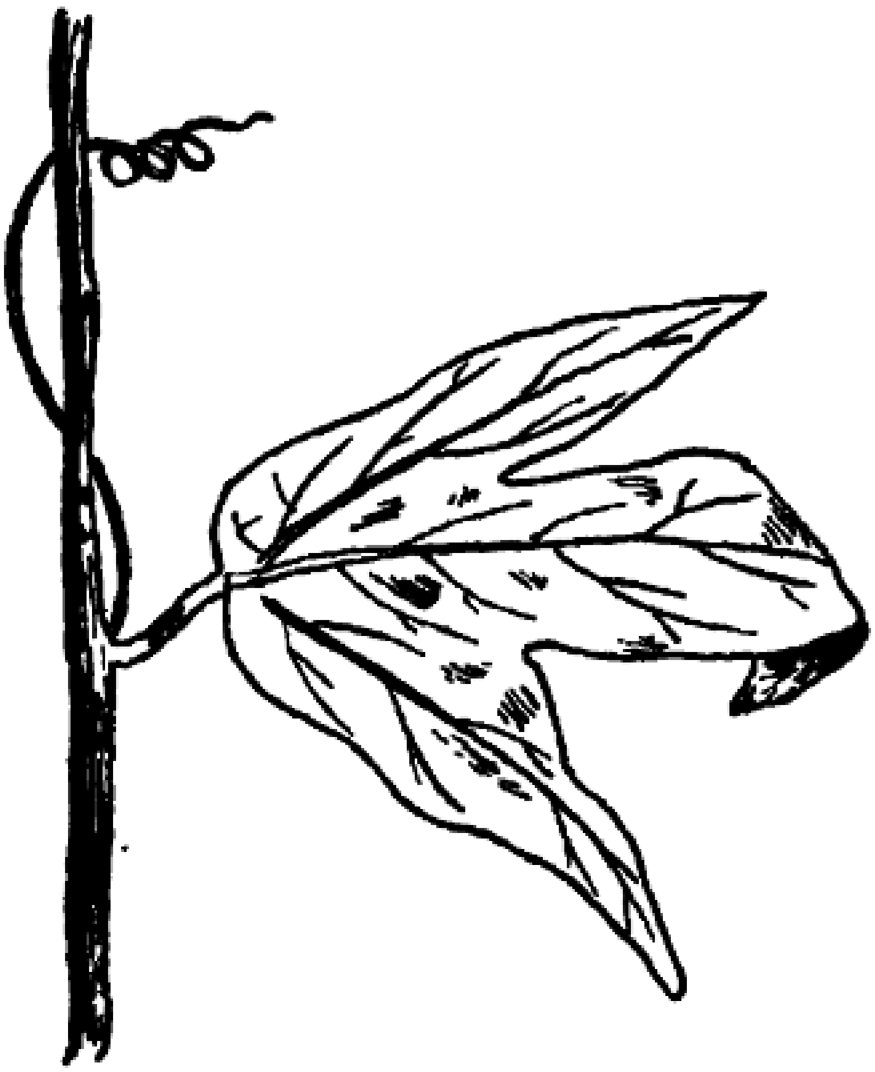
II. Stems found aboveground—

The stems that are found on the ground are either erect or they trail along the ground. The former is known as Erect and the latter Prostrate or Weak.



Thorn

Erect stems are generally found all round the earth. When the growing point elongates almost straight and the main stem bears lateral branches in acropetal succession so that the whole plant looks like a conical structure, it is called **excurrent** as in pine, deodar. When the stem by repeated branching assumes a bushy structure and the main axis is difficult to find out, it is called **deliquescent** as in Banyan, Jack-fruit tree. Sometimes the erect stems are very jointed as in Bamboo. These are known as **Culms.** The stems of palms are unbranched bearing a tuft of leaves. These are known as **Caudex.**



Tendril

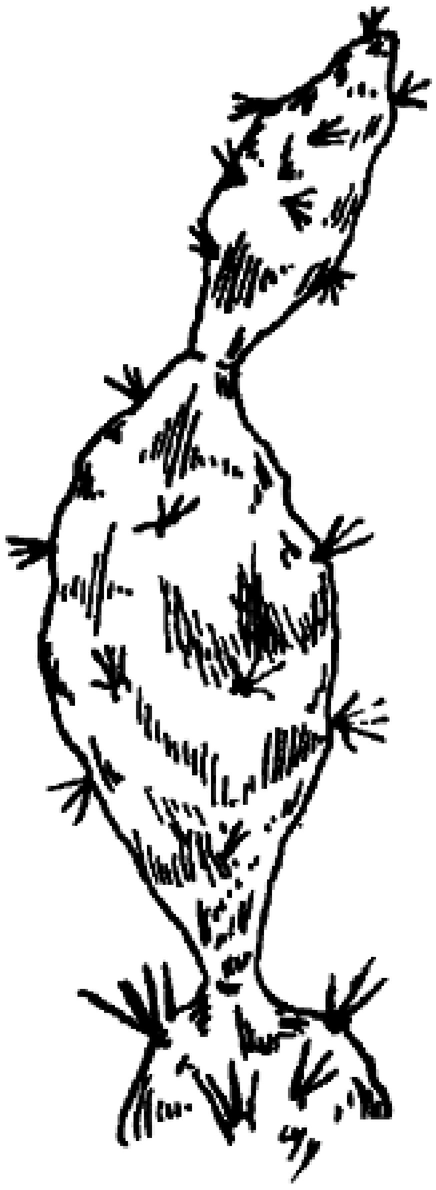
The aerial stems are sometimes modified as follows: —

(1) **Tendril**—the stem is modified into a thread-like structure as in Cucurbita family (Kumra, Lau etc.). They help the plant to climb.

(2) **Thorn**—Sometimes stems are changed into spinous processes which protect the plant *e.g.* Bael, Lemon.

(3) **Cladode** and **Phylloclade**—these are flat leaf-like structures which are modified stems. They arise in the axil of leaves and often bear flowers. When the flat structure has but one internode, it is called cladode *e.g.*

Asparagus (Satamooli). When there are several internodes it is known as Phylloclade *e.g.* Opuntia (Phanimonsa).



Phylloclade

Weak Stems—

When the plants are not erect, they may trail along the ground and are known as the trailing plants while others climb up on some support and are known as climbing plants.

Weak plants may be :—

(*a*) **Procumbent,** when they travel along the ground but do not root at the nodes *e.g.,* Basella (Puin).

(*b*) **Decumbent,** when the growing point rises while the other part remains flat on the ground as in Portulaca.

(c) **Creeping,** when they root at the nodes *e.g.*, Cynodon (Durba grass).

There are several modified forms of subaerial stems:—

(1) **Stolon,** when the plant arises as a branch and travels over the ground and forms an arch rooting at the place where it meets the soil *e.g.* Hydrocotyl (Thulkuri), Gooseberry.

(2) **Sucker,** travels along the ground and the separated plant is capable like the stolon to lead an independent life *e.g.*, Mint (Pudina), Chrysanthemum.

(3) **Runner,** it is a thin prostrate branch. It is produced from axillary bud, goes to some distance and produces roots and becomes an independent plant when separated as in Oxalis.

(4) **Offset,** it is a short, thick and prostrate branch. When separated it becomes an independent plant as in Pistia (Pana).

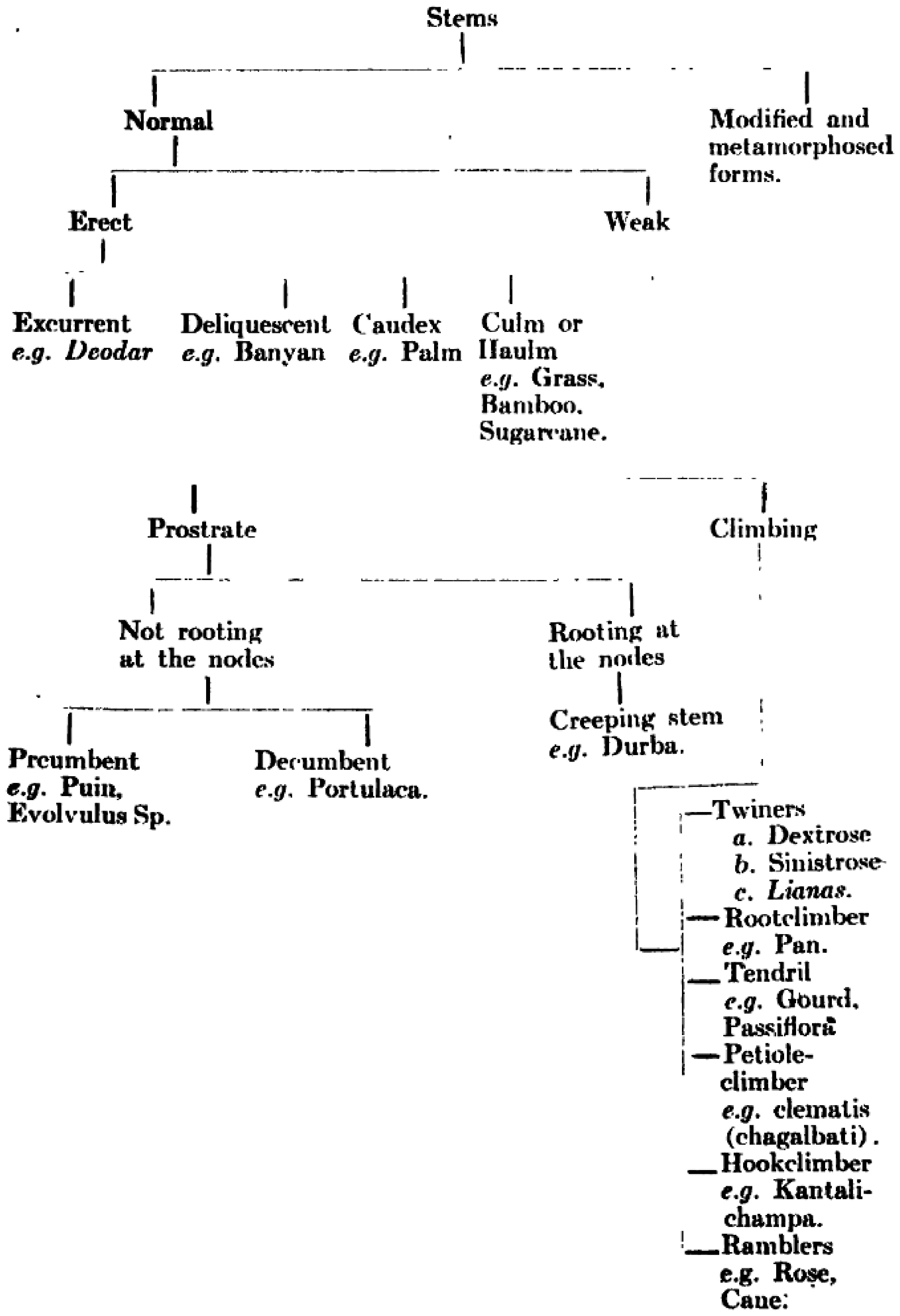
Climbing plants may be :—

(1) **Tendril climbers,** which climb by means of tendrils *e.g.*, Cucumber.

(2) **Root climbers,** give rise to additional roots from the stem to climb up as a support *e.g.*, Piper betle (Pan).

(3) **Hook climbers,** when the plants rise up by hooks on their supports *e.g.*, Artabotrys (Kantali Champa).

(4) **Stem climbers,** when plants twine up their support by means of stems *e.g.*, Dolichos.



- Stems
  - Normal
    - Erect
      - Excurrent *e.g. Deodar*
      - Deliquescent *e.g.* Banyan
      - Caudex *e.g.* Palm
      - Culm or Haulm *e.g.* Grass, Bamboo, Sugarcane.
    - Weak
      - Prostrate
        - Not rooting at the nodes
          - Procumbent *e.g.* Puin, Evolvulus Sp.
          - Decumbent *e.g.* Portulaca.
        - Rooting at the nodes
          - Creeping stem *e.g.* Durba.
      - Climbing
        - Twiners
          - a. Dextrose
          - b. Sinistrose
          - c. *Lianas.*
        - Rootclimber *e.g.* Pan.
        - Tendril *e.g.* Gourd, Passiflora
        - Petiole-climber *e.g.* clematis (chagalbati).
        - Hookclimber *e.g.* Kantali-champa.
        - Ramblers e.g. Rose, Cane.
  - Modified and metamorphosed forms.

Modifications of Stem

Subaerial

1. For propagation
    - a. *Runner* eg. Oxalis Sp.
    - b. *Stolon* e.g. Hydrocotyl Sp.
    - c. *Offset* e.g. Chrysanthemum Sp.
2. For climbing
    - e. *Tendril* e.g. Passiflora
3. For self-defence
    - f. Thorn e.g. Lemon
4. For assimilation
    - g. *Phylloclade* e.g. Phanimansa.
    - h. *Cladode* e.g. Asparagus Sp.

Subterranean

For propagation, perennation and storage

- a. ***Rhizome*** **and *Rootstalk*** **e.g. Ginger, Alocasia**
- b. ***Tuber*** **e.g. Potato**
- c. ***Bulb*** **e.g. Onion**
- d. ***Corm*** **e.g. Ol.**

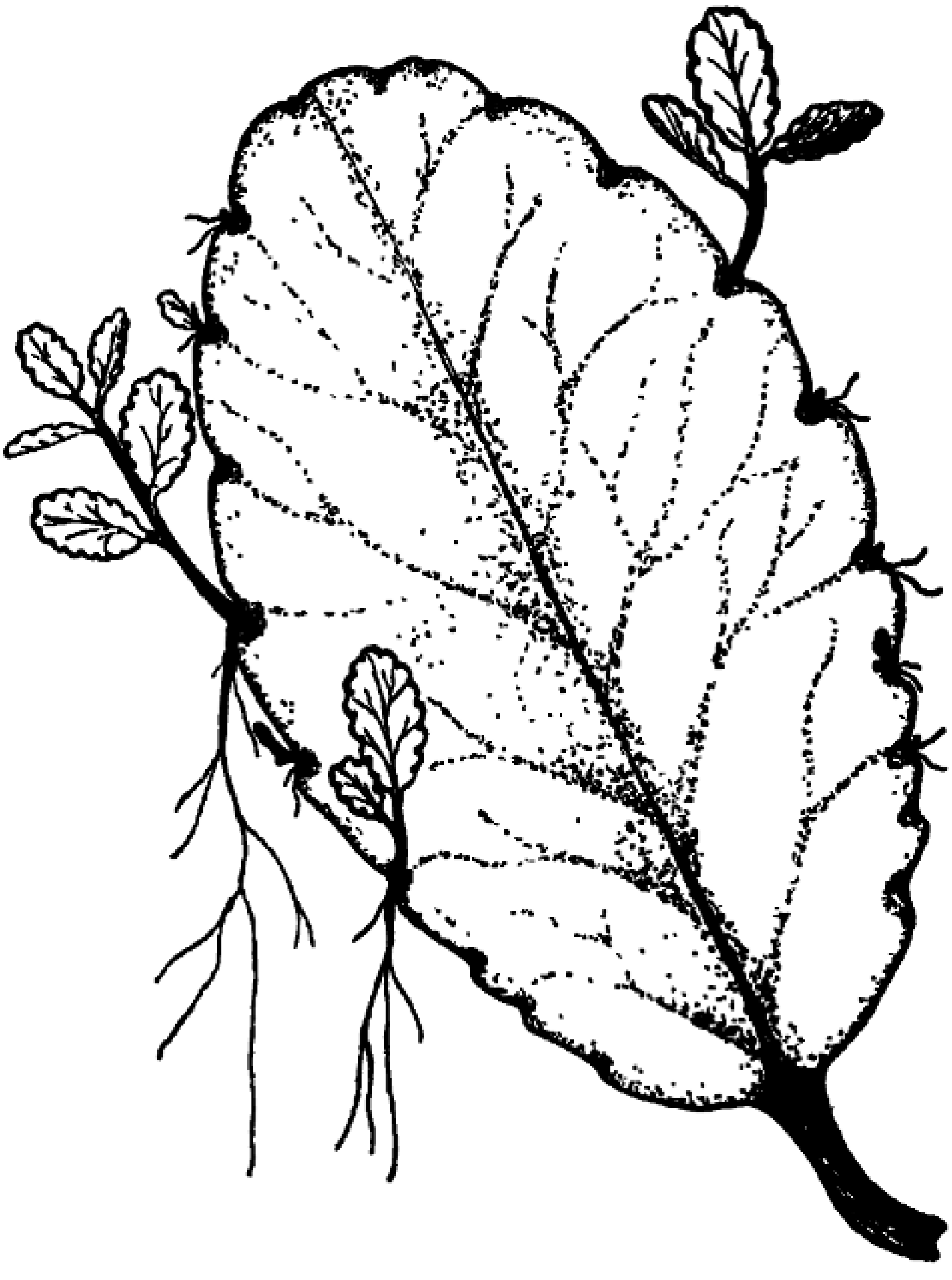
Bud—

Bud is really a condensed shoot having a delicate growing point with a rudimentary axis and having compressed nodes and inter-nodes surrounded by minute rudimentary leaves.

Plants generally show their development by the growth of the terminal bud where leafy structures are at first found to be in a compressed condition. The compressed structure shows small leaves in various stages of growth. This rudimentary structure consisting of a number of leaves, nodes and inter-nodes in a miniature form is called a **Bud.** The Buds are generally found at the apex of the main stem or branches. Another conspicuous position is the axil of a leaf. The buds found at the apex are called **Terminal** while those at the axil are called **Axillary.** Usually one bud is found at the axil but if there be more than one bud, the additional buds are known as **Accessory** buds.

Normal and **adventitious** buds—

Buds when they arise from their normal positions are said to be normal but sometimes they are found to arise from abnormal position when they are known as adventitious buds *e.g.*, Leaf of Bryophyllum (Pathorkucha).



Bryophyllum

Dormant and **deciduous buds**—

Sometimes the buds without unfurling the foliage remain in an inactive state only to renew their growth when there is any necessity. In cold regions of the world, the buds protect the plant by remaining dormant in the unfavourable period and grow when the rigours of climate disappear.

Buds may appear but fall away before showing the foliage. Such buds are called *deciduous* buds.

Sometimes buds might appear but on falling to the ground do a distinct service since by developing into an independent plant, such a condition gives an example of vegetative propagation. These buds are called *Bulbils* *e.g.* Dioscorea (Chuprialoo).

Buds can be classified broadly into two types :--

(1) *Vegetative* or Leaf-buds.

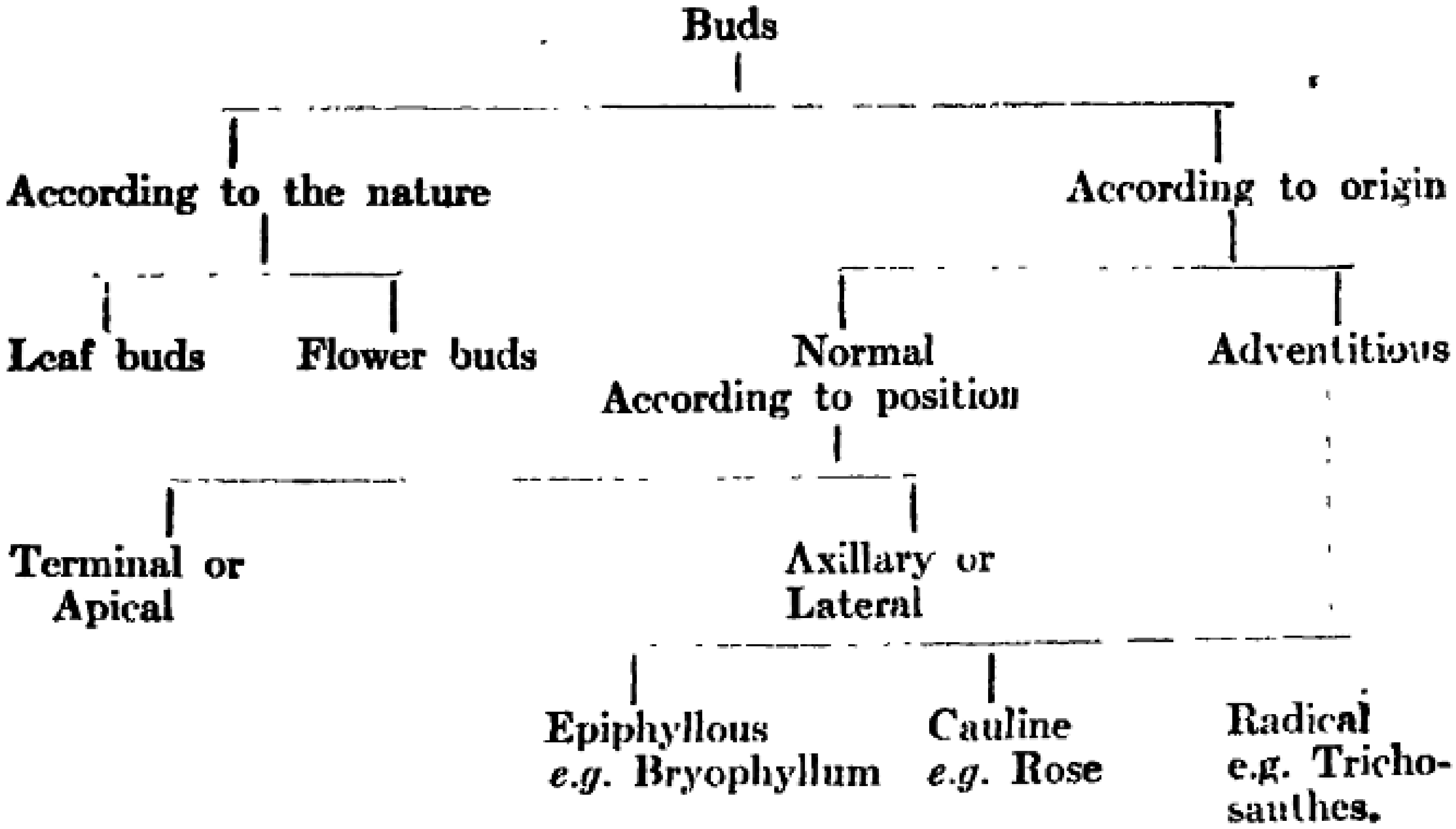
(2) *Reproductive* or flowerbuds.

The bud developing ordinary foliage is called a Vegetative bud while the bud which develops into a flower is called a Reproductive bud.

Buds are often without any protective covering or contrivance; such buds are called Naked buds. These buds are found in tropical countries.

Buds are often protected by means of scale like structures. Such Buds are known as scaly buds. Sometimes leafy structures overlap or the outer leaves become thick and fleshy and still another mechanism is found namely a resinous secretion or the presence of hairs on the buds to protect them from drying.

BUDS


Buds
According to the nature
Leaf buds
Flower buds
According to origin
Normal
According to position
Adventitious
Terminal or Apical
Axillary or Lateral
Epiphyllous e.g. Bryophyllum
Cauline e.g. Rose
Radical e.g. Trichosanthes.

CHAPTER XIII

BRANCHING.

The lateral development of similar parts is branching. There are two types of branching :—

(1) *Lateral*, (2) *Dichotomous*.

(1) Lateral branching—the main axis elongates and from the sides, branches arise by the development of axillary buds. Lateral branching is of two types :—

(*a*) *Racemose*, (*b*) *Cymose*.

(*a*) ***Racemose*** branching when the main axis has an unlimited growth and branches arise in acropetal succession *i.e.* the youngest branch is near the apex and the older ones near the base of the plant.

(*b*) *Cymose* branching does not show the unlimited growth of the apex, but the apical bud is arrested in its growth.

The buds below the apex take up the growth and are similarly followed by other buds, so the daughter branches are more prominent and strong than the parent axis. This type of branching is called *Cymose*.

(1) In the case of cymose branching, one branch develops followed by such other branches, it is called *Uniparous cyme* or *Monochasium*. If the branch system devolops on one side, it is called **Helicoid** but if alternate branches develop it is called **Scorpioid.**

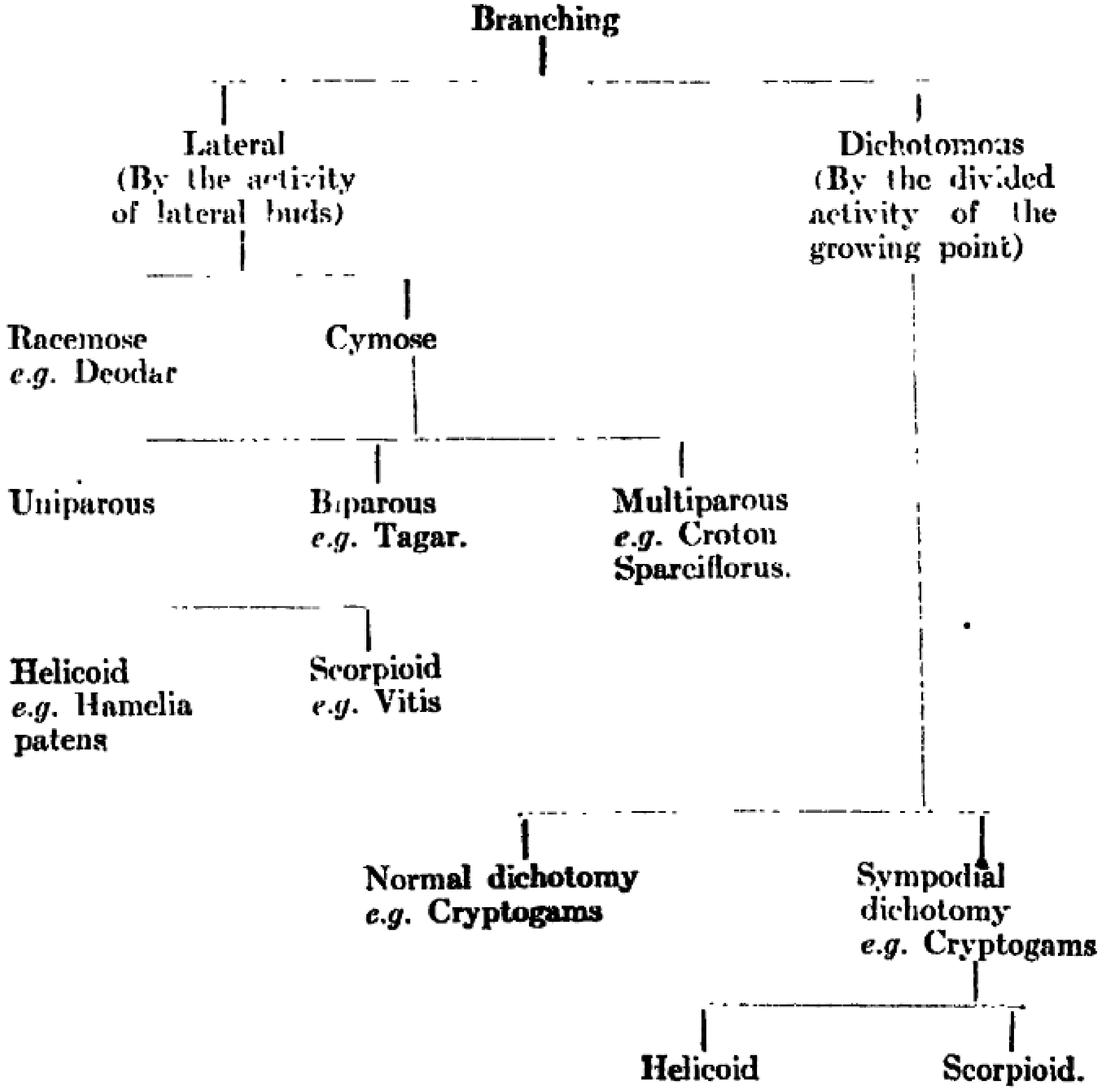
(2) If two such branches develop it is called **Biparous cyme.**

(3) If more than two branches develop it is called **Multiparous cyme.**

Dichotomous Branching—

When the main **axis divides** equally into two branches and are followed by **similar branches**, it is known as **Dichotomous** branching. **It occurs** in the Cryptogams.

If branches develop **on one** side, it is **Helicoid** and when alternate **development of branches** is observed it is called **Scorpioid.**


Branching
Lateral (By the activity of lateral buds)
Dichotomous (By the divided activity of the growing point)
Racemose e.g. Deodar
Cymose
Uniparous
Biparous e.g. Tagar.
Multiparous e.g. Croton Sparciflorus.
Helicoid e.g. Hamelia patens
Scorpioid e.g. Vitis
Normal dichotomy e.g. Cryptogams
Sympodial dichotomy e.g. Cryptogams
Helicoid
Scorpioid.

CHAPTER XIV

LEAF.

Leaf is the *lateral dissimilar appendage* of the stem or branch. It is the laboratory of the plant where the simple food-materials collected from the soil and air are converted into organic food not only for the use of the plant but also for the welfare of the living animals which have to depend upon plants directly or indirectly for their nutrition. They arise in acropetal succession on the stem. The ordinary leaves are known as foliage leaves and are usually green in colour. They sometimes take other forms and colours.

Kinds of Leaves—

(1) **Ordinary foliage leaves,** these leaves, are flat and green.

(2) **Cotyledons,** these are the primary leaves of the baby plant.

(3) **Scale-leaves,** these are found on the underground stems.

(4) **Bract leaves,** these are associated with flowers, often they are green but sometimes highly coloured *e.g.* Euphorbia pulcherrima (Lalpata)—Poinsettia.

(5) **Floral leaves,** these are the enveloping leaves of flowers, often highly coloured to attract insects *e.g.* sepals and petals.

Functions of ordinary leaves—

(1) *Manufacture of organic food* from simple materials *e.g.* **Assimilation.**

(2) *Large amount of water vapour escapes* from the leaves *e.g.* **Transpiration.**

(3) Leaves take in oxygen and give out CO_2 (carbon dioxide) *e.g.* **Respiration.**

(4) Sometimes leaves **protect** delicate structures *e.g.* **Protection.**

Parts of a Leaf—

The leaf consists of three distinct portions. The flat and broad portion is called the **Lamina or Blade or Epipodium.** The stalk-like portion below the blade is called the **petiole or leafstalk** or **Mesopodium.**

The lowest part near its attachment to the stem is called the **leaf-base or Hypopodium.**

Stipules—

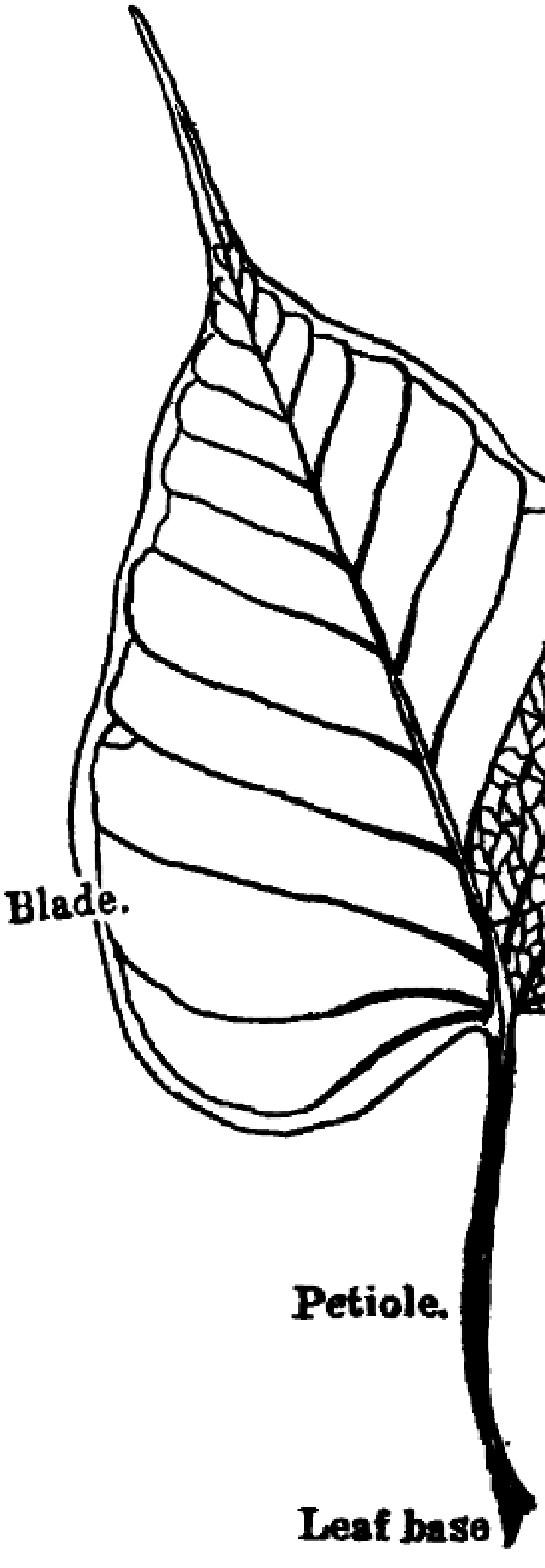
The base of the leaf sometimes shows a pair of structures which are called **Stipules.** If the leaf bears the stipules, it is called **stipulate,** while those leaves without stipules are known as **exstipulate.**

The stipules may be :—

(1) *Free lateral* when they arise from the sides of the leaf-base *e.g. Jaba.*

(2) *Foliaceous,* when the stipules are very prominent and leaflike *e.g.* **Pea.**

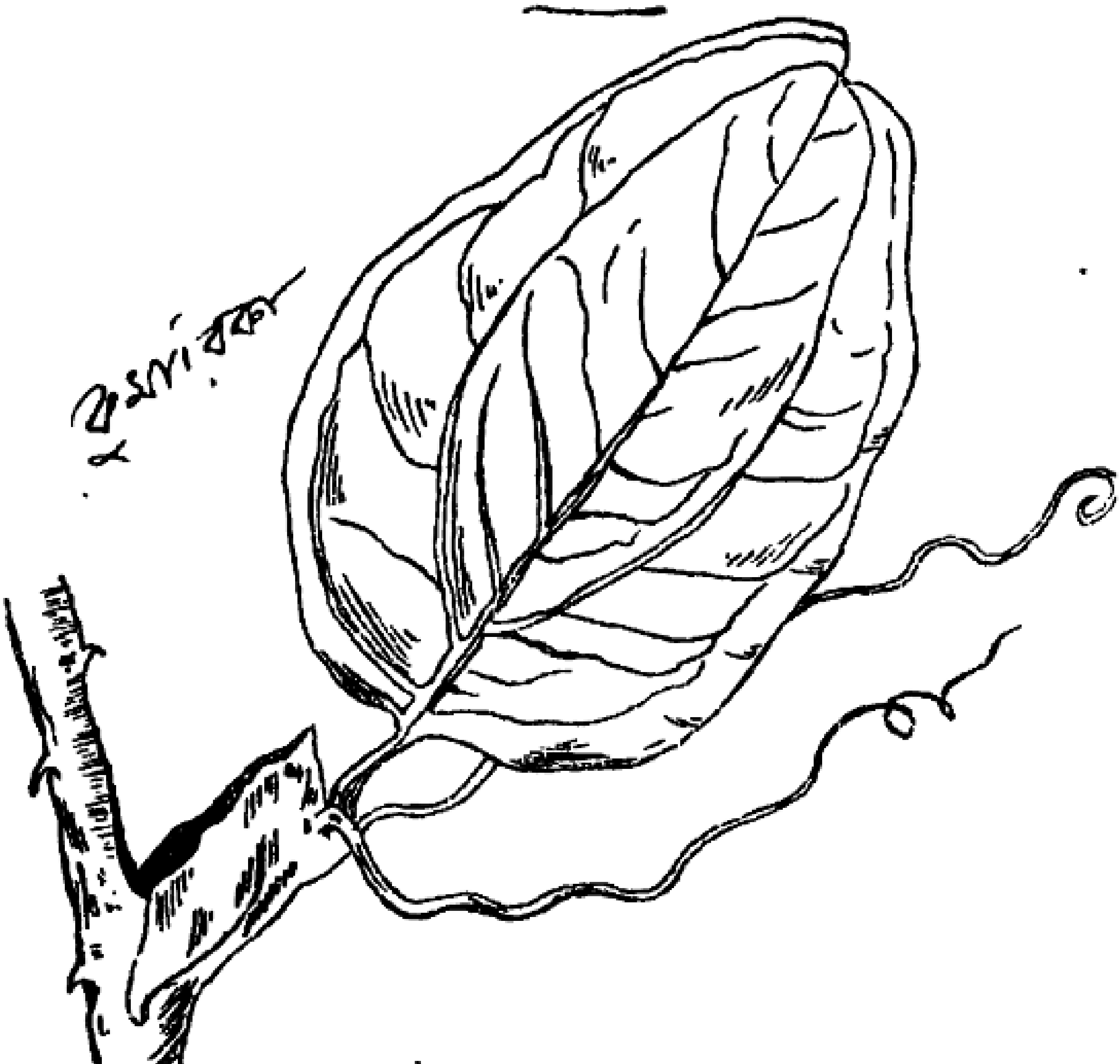
(3) *Spiny,* when the stipules are converted into spines *e.g.* Mimosa, Babla.

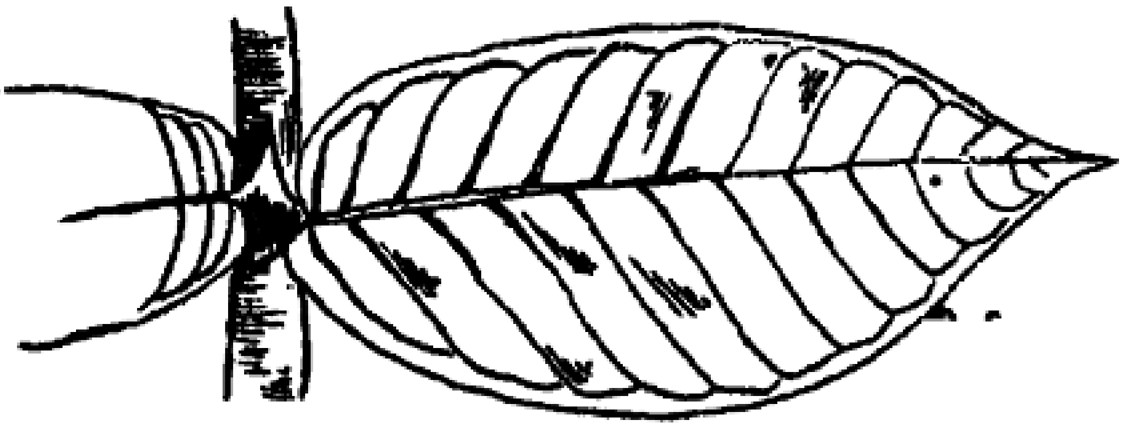


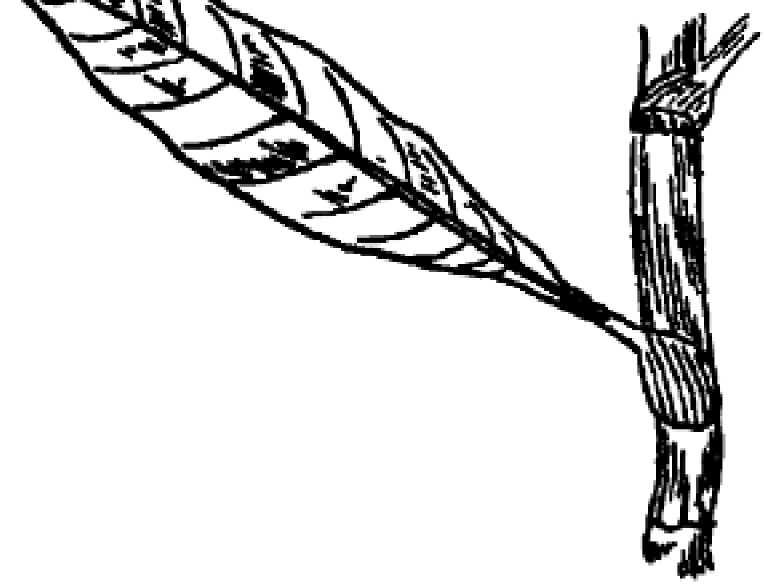
(4) **Interpetiolar,** when the stipules join up *e.g.* Rangan.

(5) **Adnate,** when the stipules enclose the base of the leaf *e.g.* **Rose.**

Tendrillarstipule.



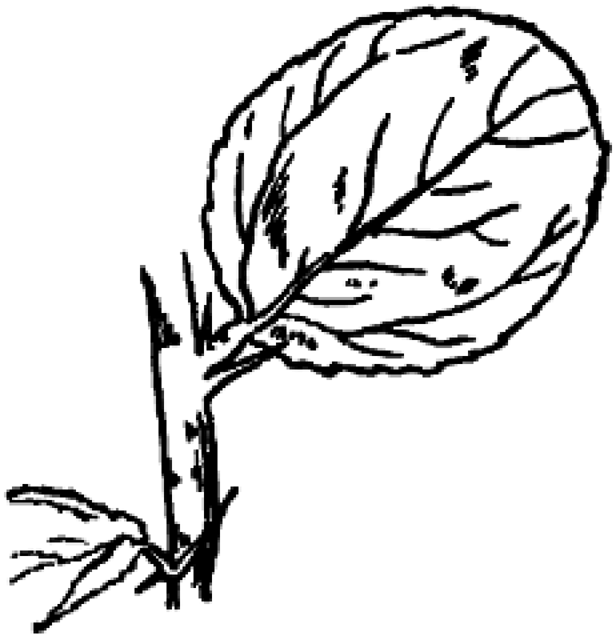




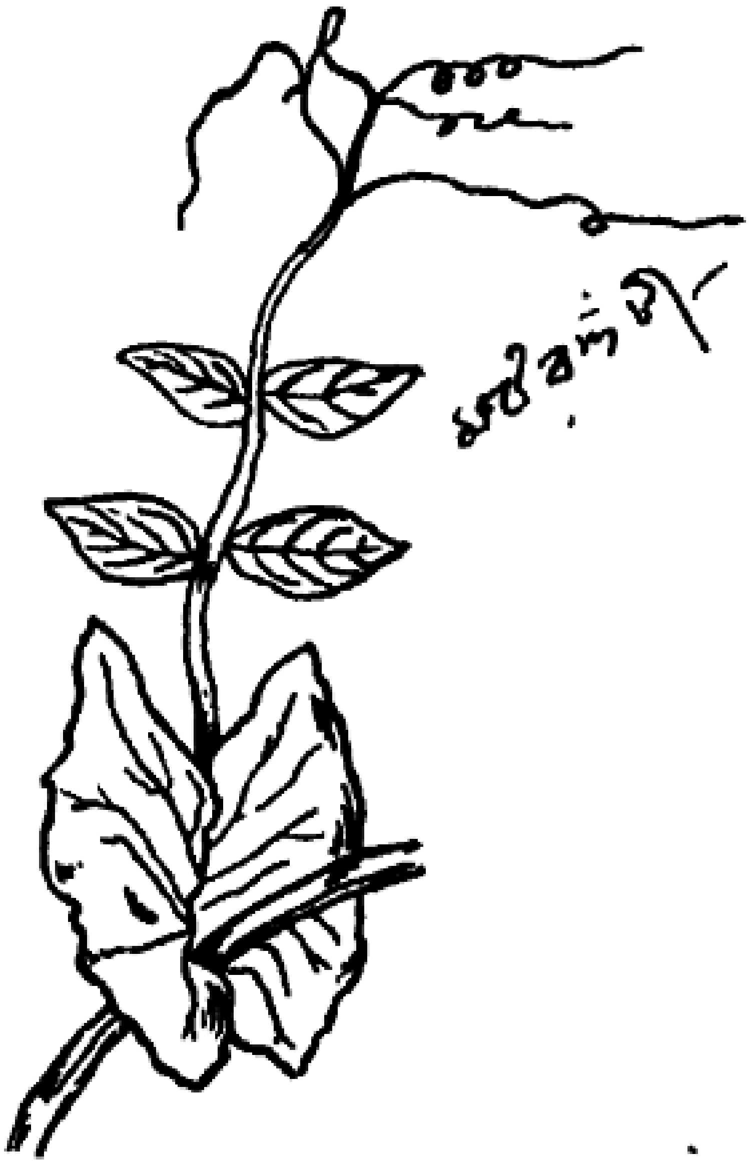
Ochreate Stipule.

(6) **Tendrillar** *e.g.* Smilax (Kumarika).

(7) **Scaly,** when they are converted into scales *e.g.* Banyan.



Spiny Stipule.



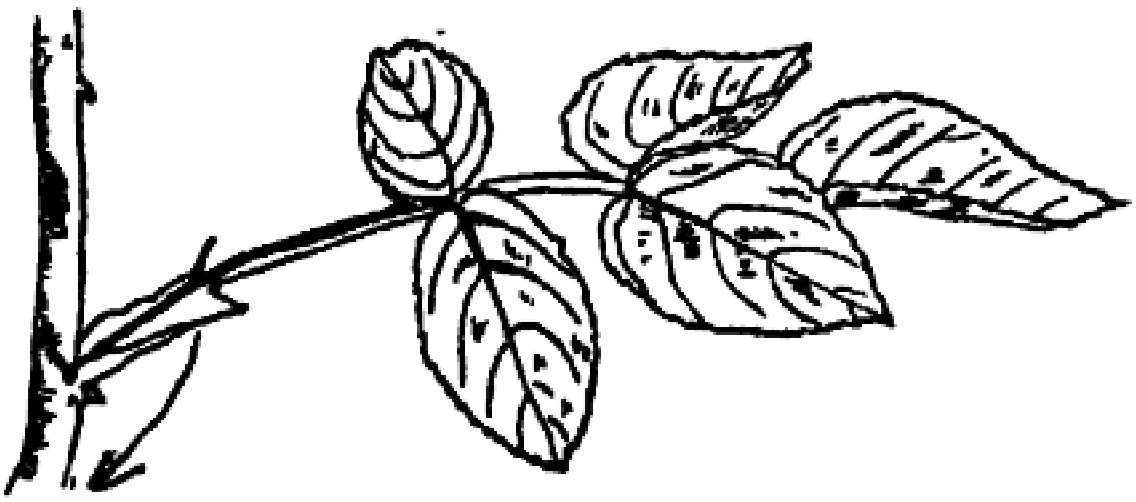
Foliaceous Stipule.

(8) **Ochreate** *e.g.* Panimarich (Poligonum).

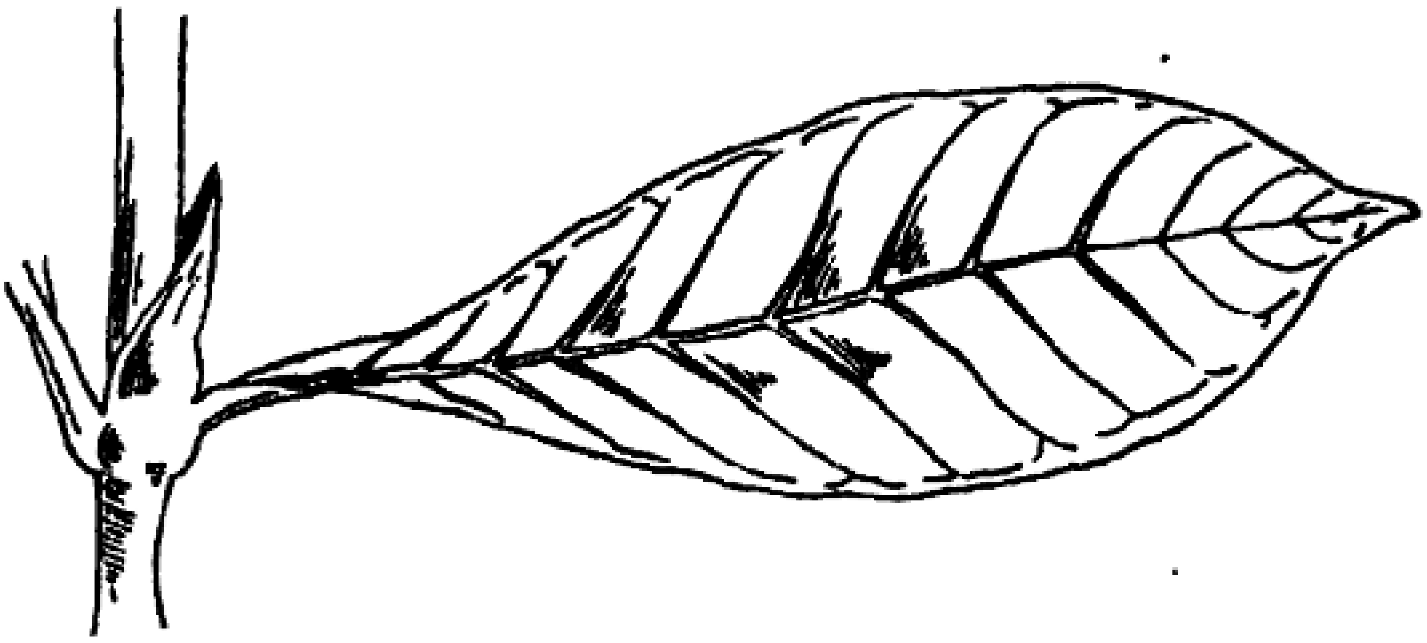
(9) **Intrapetiolar** *e.g.* Gandharaj.

Petiole of Leaf—

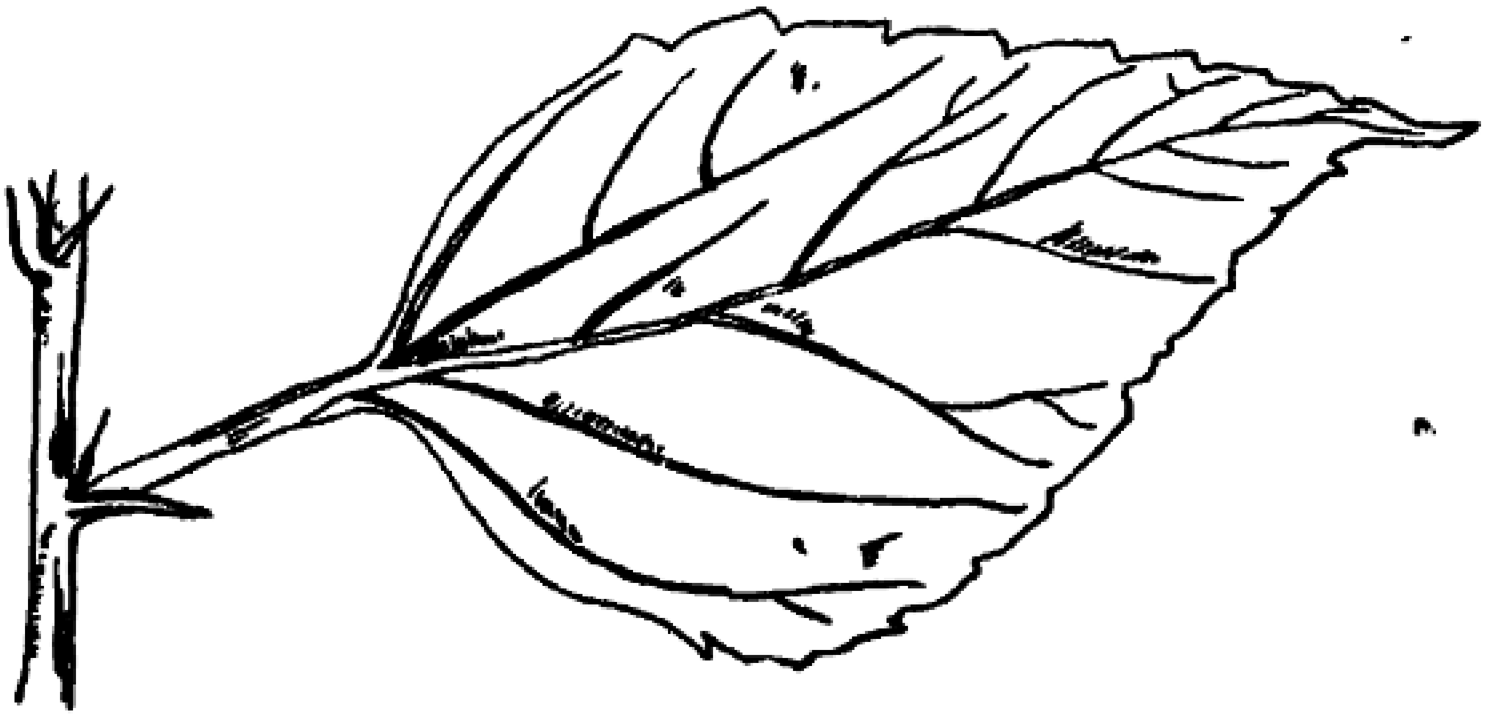
The petiole is usually round but may be long or short. Leaves with petiole are called **Petiolate** and those without it are called **Sessile.** Often the leafblade without attaining its permanent form, falls away and the work of the blade is performed by the petiole which becomes flat *e.g.* Australian Acacia. Such a petiole is known as *Phyllode.* The blade generally is flat and the terminal end is called the apex of the leaf. There is a prominent vein in the leaf running almost in the middle which is



Adnate Stipule.



Intrapetiolar Stipule.

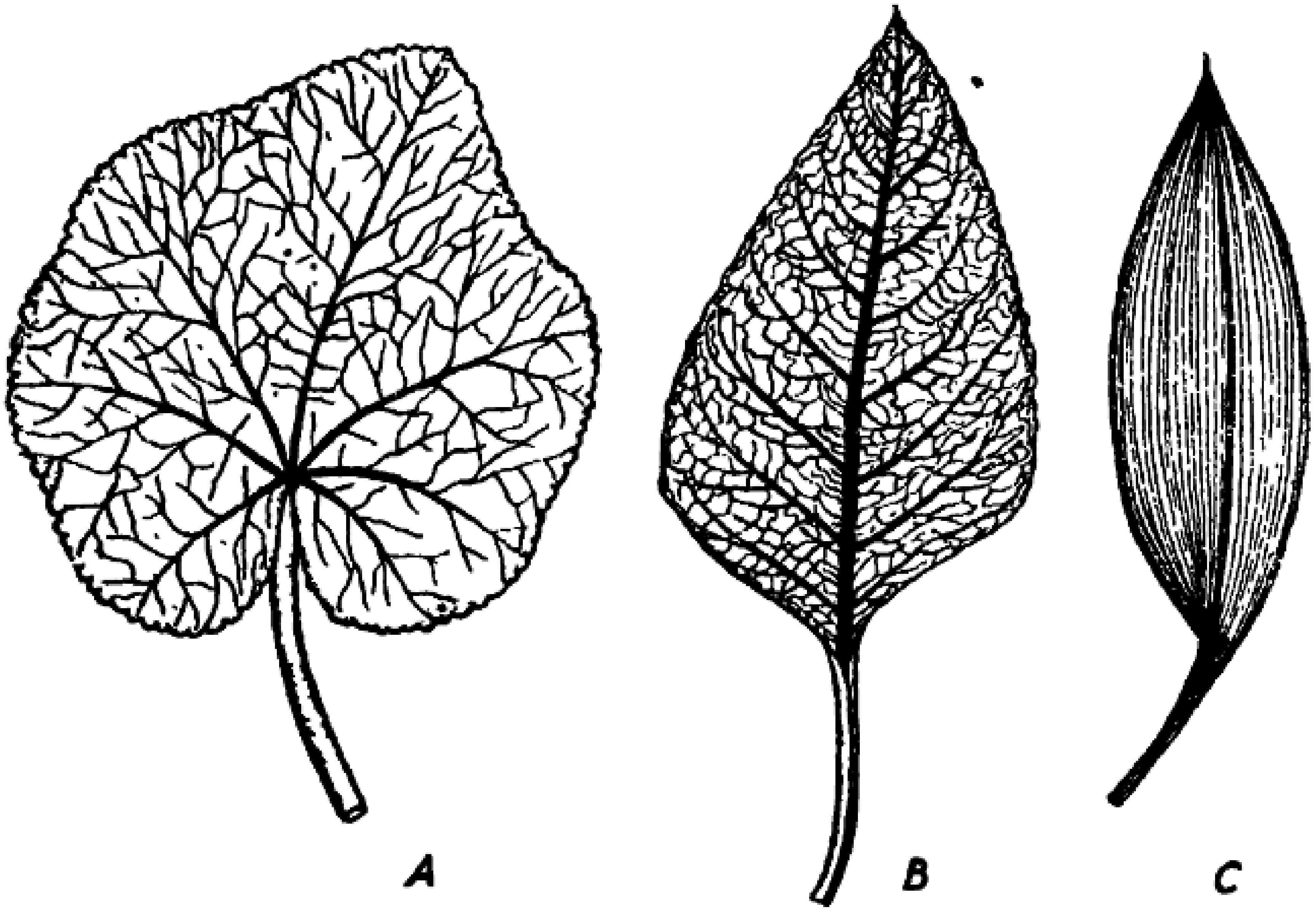


Free lateral Stipule.

called the midrib. There are other veins which form a network in the leaf coming out of the midrib.

Venation—

There are slender impressions on the leaf running all about it which are visible on looking at the leaf against light, these are due to the presence of *veins*. The arrangement of veins in a leaf is called venation.



-Palmate B—Pinnate. C—Parallel.

There are two principal types of veins, (A) **Reticulate** and (B) **Parallel.** (A) Reticulate, when the veins branch and gradually spread and form a netlike structure. *Reticulate* venations are of two types (1) **Pinnate** and (2) **Palmate.** (1) **Pinnate,** or **unicostate type** there is a prominent vein like a feather or central core of a feather and branches are given off from the sides like the pinnae of feather *e.g.* Mango. (2) **Palmate, or multicostate type** several strong veins arise in the blade of the leaf and a central midrib is absent *e.g.* Papaw, Gourd.

B. **Parallel,** when the veins arise in the leaf parallel to one another. This type is characteristic of monocotyledons *e.g.* Grass.

Parallel may be pinnate or unicostate as Plantain, canna or Palmate or multicostate as Water-hyacinth, Bamboo.

Function of Veins—

The veins carry the food solution to different parts of the leaf and also help the leaf in keeping up its form *i.e.* they give mechanical strength to the leaf.

Segmentation of leaf—

If the margin of a leaf shows incisions running to less than half the depth of the lamina, it is called **pinnatifid** *e.g.* Chandramallika. If more than half the depth of the leaf is incised, the leaf is called **pinnatipartite** *e.g.* Paniphal. If the incisions run up to the midrib, it is **pinnatisect** *e.g.* Genda.

Texture of leaf.

A leaf may be :—

(1) *Succulent* when the leaf is fleshy and juicy *e.g.* Aloe (Ghrita-kumari). (2) *Leathery* or coriaceous, when it is strong and tides over the winter season succesfully as in Pine. (3) *Herbaceous*, when the leaves fall off periodically and last but a single season *e.g.* Amra.

The leaf is studied from different points of view *e.g.* Apex, Margin and shape.

The *apex might* be of one of the following forms :—

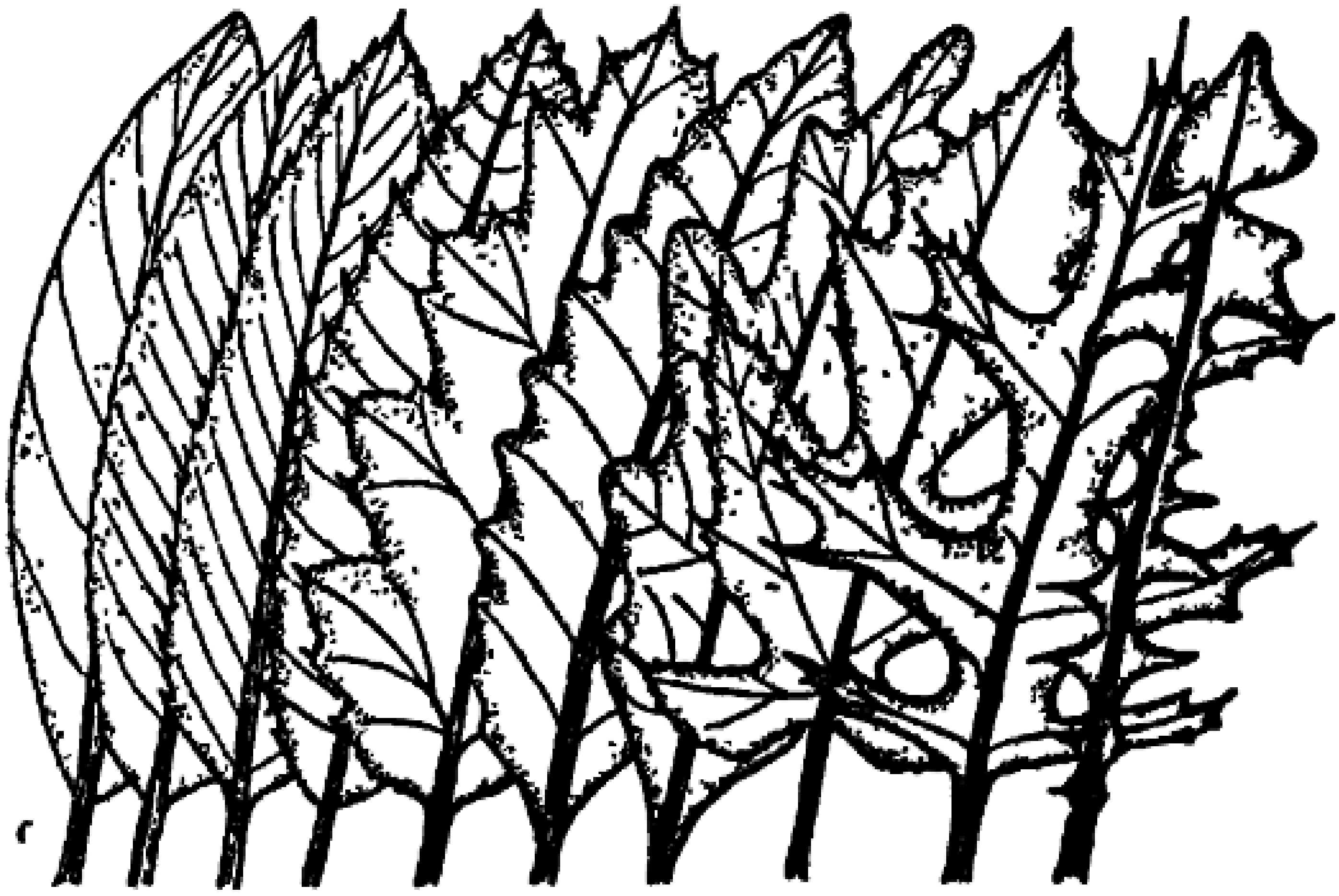
(1) *Acute,* when the apex ends in an acute angle *e.g.* Jaba.

(2) *Acuminate,* when it ends in a fine point *e.g.* Aswatha.

(3) *Obtuse,* when the apex ends in an obtuse angle *e.g.* Deshibadam (Terminalia).

(4) *Emarginate,* when there is a depression at the apex *e.g.* Oxalis (Amrul).

(5) *Tendrillar,* when the apex ends in a tendril *e.g.* Ulatchandal.

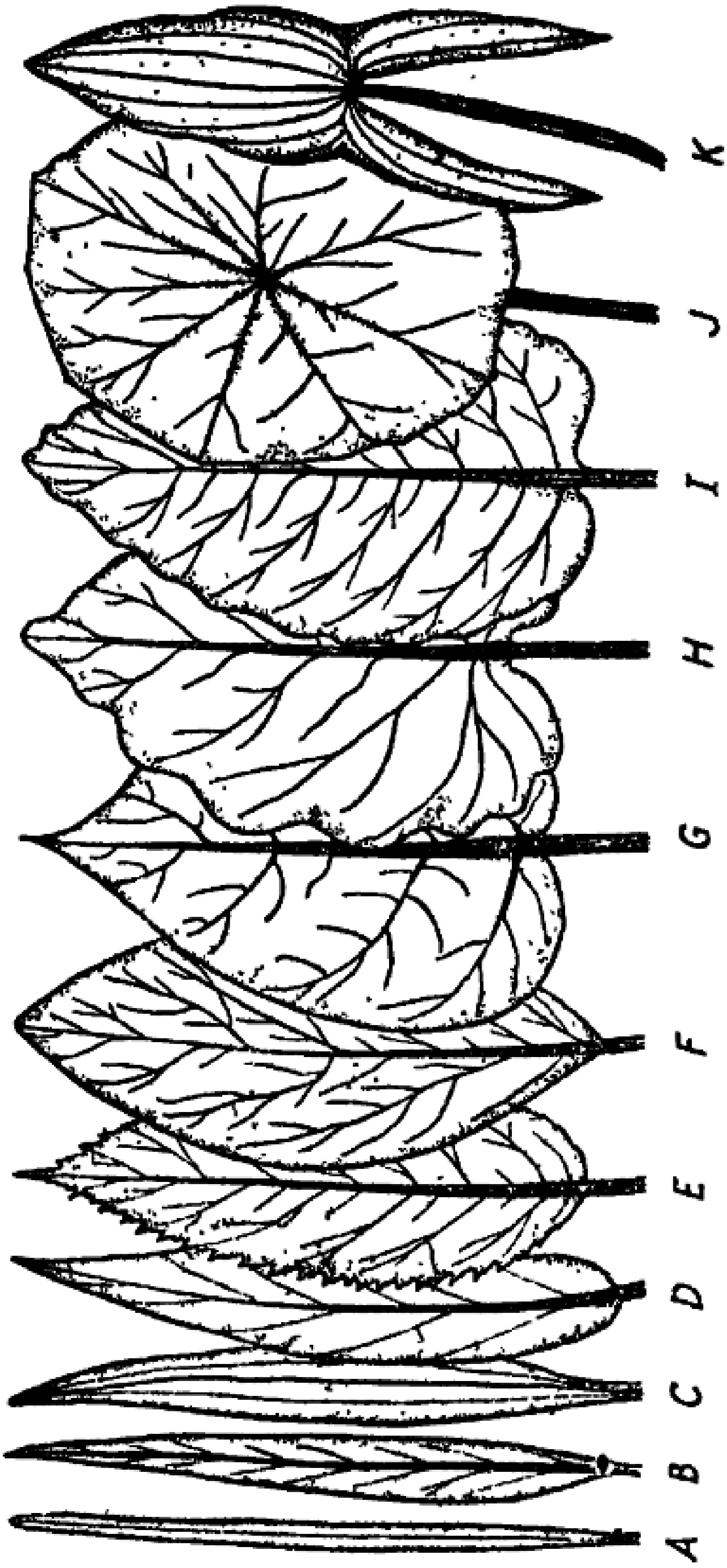


A—Entire ; B to D—Serrate ; E—Dentate ; F—Crenate ; G to J—Pinnatifid to-sect.

The *margin* may be :—

(1) *Entire,* when it has no incision *e.g.* Banyan (Bot).

(2) *Serrate,* when the incisions with their regularity give the margin a sawlike appearance *e.g.* Rose.



A—Linear; B to D—Lanceolate; E—Ovate; F—Elliptical; G & H—Cordate; I—Ovate; J—Peltate; K—Saggitate

(3) *Dentate,* when the margin projects and have toothlike incisions *e.g.* Waterlily.

(4) *Wavy,* when the margin assumes a wave-like appearance *e.g.* Deodar.

The *shape* of the leaves differs from one another and may be one of the following types :—

(1) **Linear,** when the leaf is long and more or less narrow *e.g.* Grass.

(2) **Acicular,** when the leaf is needle shaped *e.g.* Pine.

(3) **Oblong,** when the leaf is more or less rounded *e.g.* Tamarind.

(4) **Lanceolate,** when the leaf is lance—shaped *e.g.* Deodar.

(5) **Cordate,** when the leaf is heart—shaped *e.g.* Piper betle.

(6) **Reniform,** when the leaf is kidney—shaped *e.g.* Hydrocotyl (Thulkuri).

(7) **Orbicular,** when the leaf is more or less circular *e.g.* Lotus (Padma).

(8) **Auriculate,** when the base shows projections *e.g.* Calòtropis (Akanda).

(9) **Ovate** in Banyan, China rose.

(10) **Elliptical** in Nayantara.

(11) **Peltate.**

Simple and **Compound** leaves.

When the blade of the leaf is entire, it is said to be **simple** leaf. When the blade is divided into two or more parts, all articulated to a common axis, the leaf is said to be **compound** leaf. The separate parts of a compound leaf are called *leaflets.* The leaflets are similar in shape and form to the simple leaves but the axils of the leaflets never bear any bud. Buds are borne at the axil of the compound leaf.

Varieties of Compound Leaves--

They may be (1) **Pinnately** compound. (2) **Palmately** compound. Pinnately compound, when there is a central **rachis** and the leaflets or pinnae are generally borne in an opposite manner *e.g.* Rose. The pinnately compound leaves may be either provided with even number of leaflets *i.e.* the compound leaf has not a terminating leaflet. This is known as Paripinnate type *e.g.* Tamarind. Sometimes the compound leaf instead of bearing even number of leaflets bears odd number of leaflets *i.e.* there is a terminal leaflet *e.g.* Rose. This is known as *Imparipinate* type.

The pinnately compound leaves might be :—

(a) *Once pinnate.*
(*b*) *Twice pinnate* or bipinnate.
(c) *Thrice pinnate* or tripinnate.

(a) Once *pinnate,* when the pinnae are directly borne on the axis *e.g.* Rose.

(b) *Bipinnate,* when the pinnae undergo division of the second order *e.g.* Babla.

(c) *Tripinnate,* when the pinnae further divides into third order *e.g.* Sajina.

2. Palmately compound, when there is no rachis but the leaflets arise from a common point. According to

the number of leaflets a compound leaf of the Palmate type is:—

(1) *Unifoliate,*
(2) *Binnate,*
(3) *Ternate* etc. according as the leaflets number one, two or three etc.

Difference between Simple and Compound Leaves—

1. The blade is *entire* in a simple leaf while the blade undergoes division in a compound leaf.

2. The axil of a simple leaf bears a *bud* while the axil of the leaflets does not bear any bud but the rachis bears a bud.

3. The simple leaf bears *stipules* while the leaflets do not bear the *stipules* but the rachis might bear them.

Distinction between a Branch and a Compound Leaf—

(1) The branch bears buds at the terminal point but the compound leaf does not bear any terminal bud.

(2) The leaves of branches bear buds in the axils but the leaflets of the compound leaves do not bear any bud in the axil.

Prefoliation—

Prefoliation signifies the arrangement of leaves in the bud. It includes the arrangement of individual leaves i.e. how each leaf is arranged by itself and is known as **Ptyxis,** while the arrangement of the leaves with one another in the bud is known as **vernation.**

Ptyxis may be :—

(1) *Plane,* when the leaf is not folded *e.g.* Bakash (Adhatoda),

(2) *Reclinate or inflexed,* when the upper part of the leaf is bent down on the lower part,

(3) *Conduplicate,* when the leaf is folded lengthwise along the midrib *e.g.* Magnolia (Champa), Rose,

(4) *Plicate,* when the blade is folded back and forth along the main veins like a closed fan *e.g.* Fan-palm,

(5) *Circinate,* when the leaf is rolled from the tip downward to the base as in ferns,

(6) *Convolute,* when the leaf is rolled lengthwise from side to side, scroll-like *e.g. Plantain-leaf,*

(7) *Involute,* when both edges of the leaf are inrolled lengthwise on the upper surface towards the midrib *e.g.* Lotus, Waterlily,

(8) *Revolute,* when both edges are inrolled on the lower surface *e.g.* Karavi.

Vernation—

This is (1) *Imbricate,* when the leaves in a bud overlap others.

(2) *Valvate,* when the leaves touch only by margins.

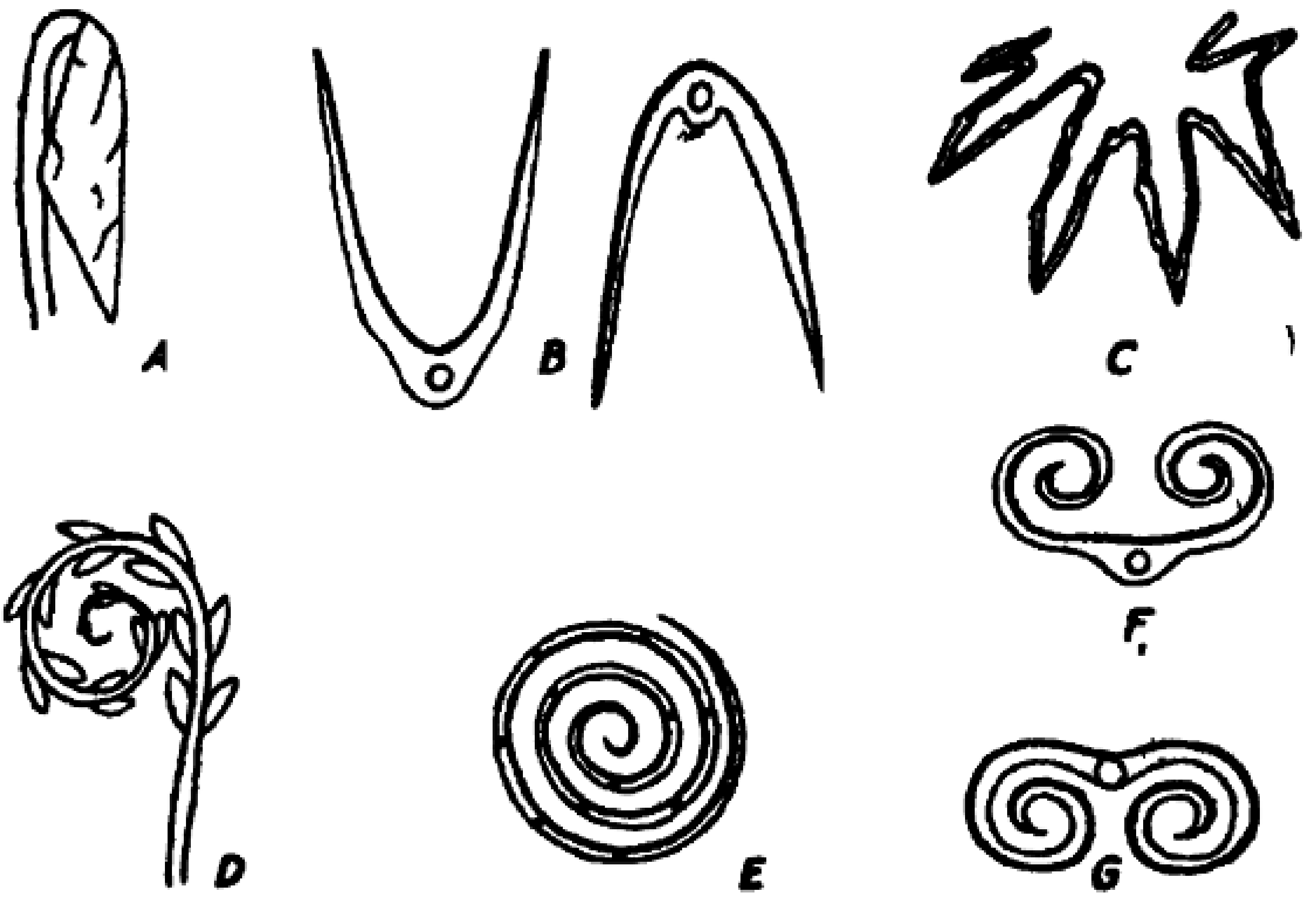
(3) *Twisted,* when one margin is inwards and the other outwards overlapping another inner margin of the leaf.

Phyllotaxis—

Phyllotaxis is the mode of arrangement of leaves on the stem or branches. Phyllotaxis may be

(1) *Opposite,* (2) *Alternate,* (3) *Whorled.*

Leaves are arranged on the stem in various ways in order to expose their surfaces to suitable amount of solar rays and air. If the leaves are congested in a small space, the chances are that the leaves will not be able to get proper nourishment and unhealthy conditions will bring disaster to them.



A=Reclinate ; B=Conduplicate ; C=Plicate ; D=Circinate ; F=Involute ; E=Convolute ; G=Revolute.

(1) *Opposite,* when one leaf finds another opposite to it in a node *e.g.* Tulsi (Ocimum).

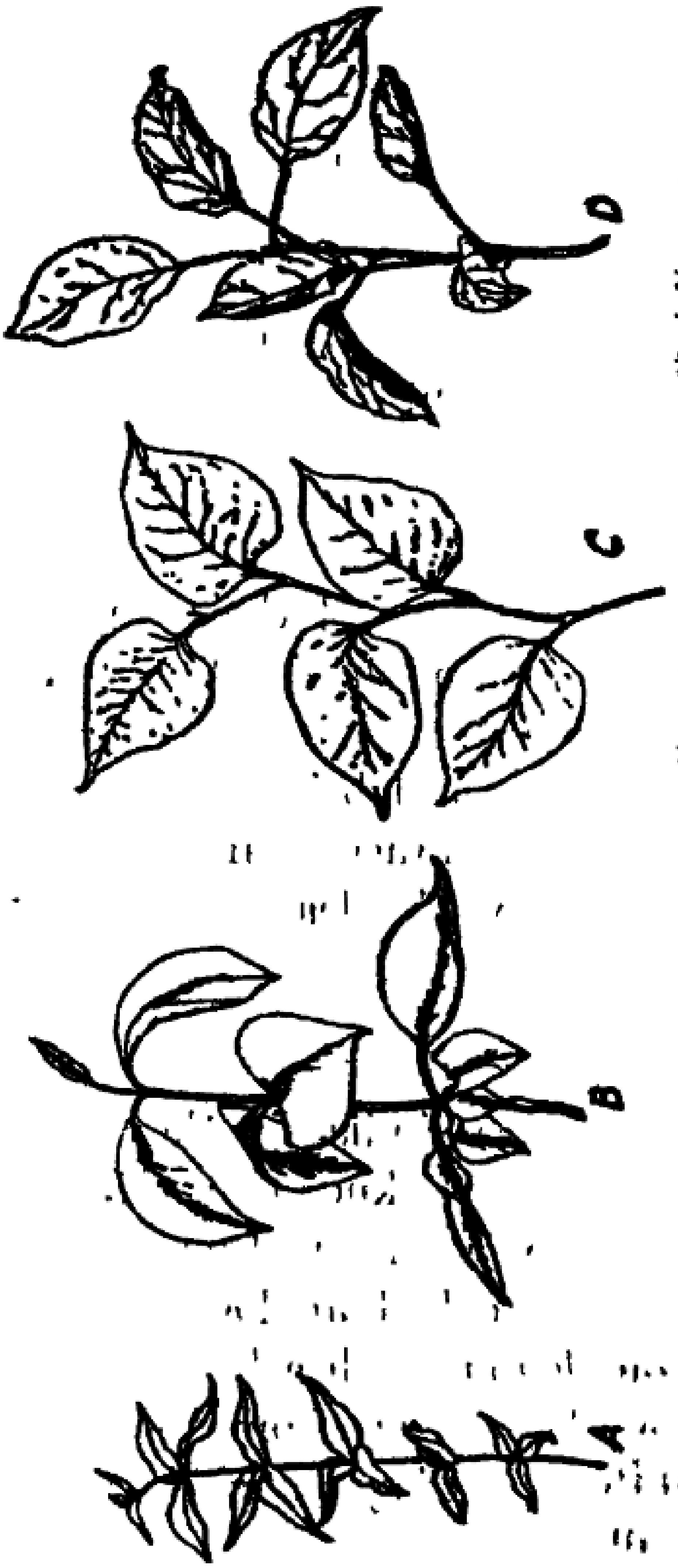
(2) *Alternate,* when one leaf is found in a node *e.g.* Mango, Tobacco, Mustard.

(3) *Whorled,* when more than two leaves arise from a node *e.g.* Karabi, Devil tree (Chhatim).

The alternate arrangement is known as spiral arrangement and several laws govern it,

(1) Leaves are found on different sides of stem,

(2) An imaginary line can be drawn connecting the bases of the leaves which is known as the *genetic spiral.*



A=Whorled. B=Decussate. C=Alternate. D=Alternate
Phyllotaxis.

(3) If vertical lines be drawn on the stem, the leaves will lie on those lines, the lines are called *orthostichies.*

(4) The distance between any two consecutive leaves along the Genetic spiral, is measured in the fraction of the circumferance of the stem and is called the *lateral divergence,* while the angle subtended by the lateral divergence, is known as Angular divergence. It is measured in degrees. When the number of orthostichies is two, the arrangement is known as Distichous. The divergence is $\frac{1}{2}$ and the angular divergence is $\frac{1}{2}$ of 360° =180° *e.g.* Grasses. When the number of orthostichies is three, the arrangement is called Tristichous, when five Pentastichous and so on.

Leaf-mosaic—

Plants sometimes spread their leaves in the form of a continuous surface and utilise the sunlight to the best advantage. This arrangement is followed to prevent overlapping of leaves and bring the light to the reach of every leaf. The appearance is an adaptation of the plant for mutual welfare of the leaves. *e.g.* Oxalis, Krisnakali etc.

Homology and **Analogy—**

Organs which are similar in their origin but perform different functions are known as *Homologous* organs. Organs which perform similar function but are different morphologically are called analogous organs. The tuber of potato is homologous with a branch. Floral leaves and ordinary foliage leaves are homologous structures. The tuber of potato is analogous with radish because their function is similar.

CHAPTER XV

INFLORESCENCE

It is known that flowers arise from buds which are different from buds giving rise to foliage leaves. The buds are called floral buds. They may be terminal or axillary. A floral bud arises usually from the axil of a leaflike structure called **Bract.** The *Bracts* are generally coloured and much smaller in size than the foliage leaves. Bracts mainly perform the function of attraction and protection. Bracts may be :—

(1) *Coloured*, when they are known as petaloid bracts *e.g.* Baganbilas (Bougainvillea).

(2) *Spathe*, when fleshy and encloses the flowers *e.g.* Plantain.

(3) *Glumes*, much smaller in size *e.g.* Grass.

(4) *Epicalyx*, forms a ring round the base of the flower *e.g.* Jaba.

(5) *Involucre*, when a number of bracts often found round a number of flowers collected together *e.g.* Sunflower.

Inflorescence is a branch system bearing a number of flowers. There are two types of inflorescence :—

(A) **Racemose.** (B) **Cymose.**

Racemose inflorescence is characterised by an indefinite growing point. The oldest flowers are found towards the base. The youngest flowers are near the apex. The flowers are said to open in acropetal succession. Sometimes the axis of this type of inflorescence becomes greatly shortened and assumes a flat disk-like structure, in such cases the flowers open from the circumference towards the centre. There are several types of Racemose inflorescence.

Racemose inflorescence.

Cymose inflorescence bears a terminal flower *i.e.*, the ultimate growing point is defined by a flower. Here the order of opening of flowers is reversed. The youngest flower is found near the base of the inflorescence and the oldest flower at the apex. In cymose inflorescence, if the disc becomes flat and the axis of the inflorescence shortend, the flowers open from the centre to the circumference.

Definitions —

When there is a stalk supporting a single flower, the flower is said to be *solitary* and the stalk, is called the **Peduncle.** The stalk of the individual flowers of an inflorescence is called **Pedicel** and the main axis a **Rachis.** If the flower has a pedicel, it is called Pedicillate, if not, *sessile*.

The following types of racemose inflorescence are met with :—

(1) *Raceme*, when the flowers are stalked *e.g.*, Radish, Mustard.

(2) *Spike*, when the flowers are sessile *e.g.*, Rajanigandha.

(3) *Spadix*, when the rachis is fleshy and the inflorescence is covered by a bract often showy called spathe *e.g.*, Mankachu, Plantain.

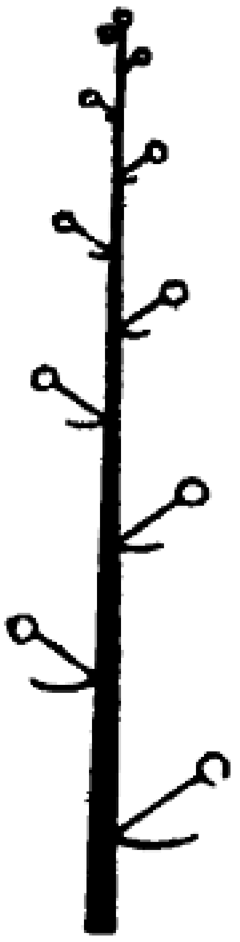
(4) *Corymb*, when the flowers by different unequal lengths of the stalks come to the same level *e.g.*, Rangan.

(5) *Catkin*, is a spike-like type of inflorescence but the *flowers* are unisexual *e.g.* Berch (Bhuryapatra), Pituli.

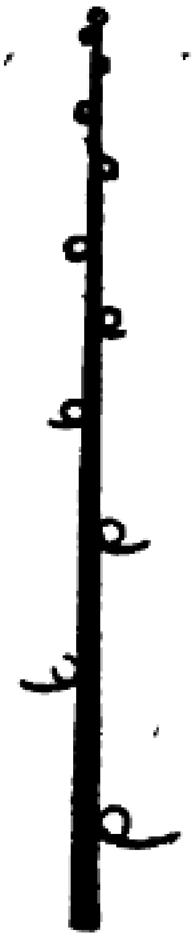
(6) *Umbel*, when the rachis is shortened and flowers with equal pedicels spring up from it *e.g.* Onion.

(7) *Capitulum* or Head, when the rachis becomes flat and forms a receptacle and the flowers develop centripetally *i.e.*, the oldest flowers open from the circumference towards the centre *e.g.*, Sunflower.

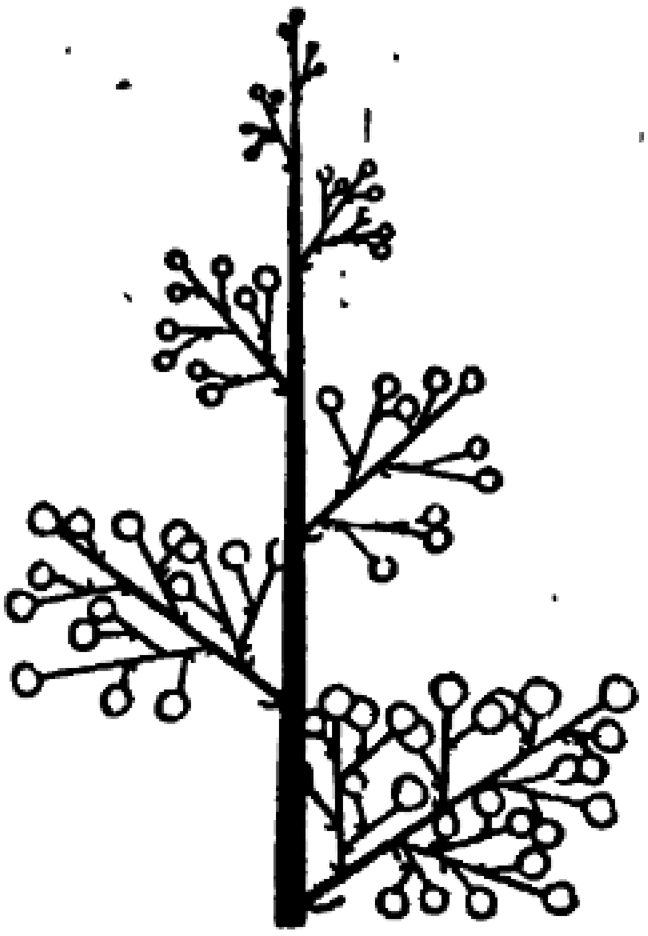
(8) *Panicle,* when the axis or rachis bears branches. These branches bear pedicelled flowers. This "raceme of racemes" is called a panicle *e.g.* Yucca.



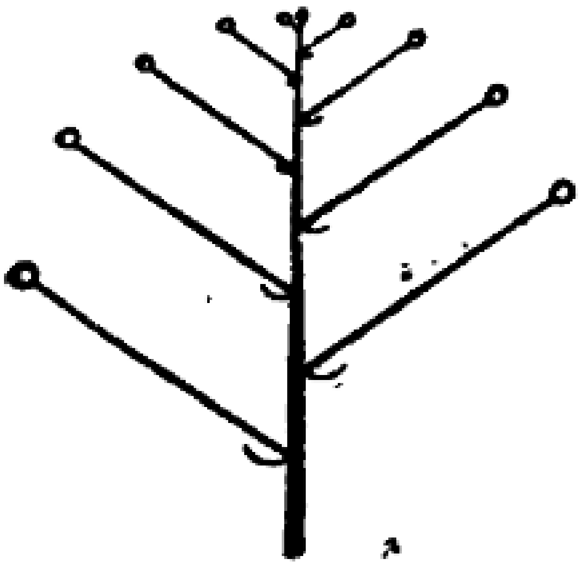
raceme



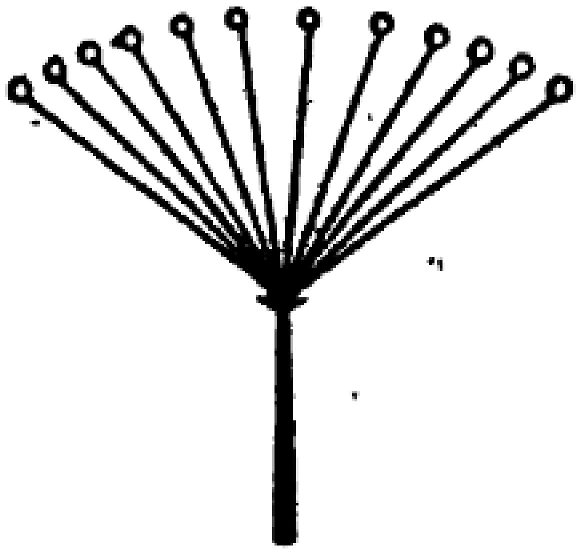
spike



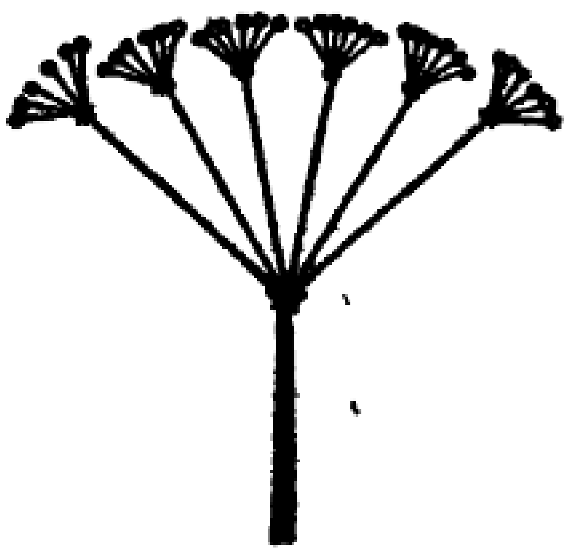
panicle



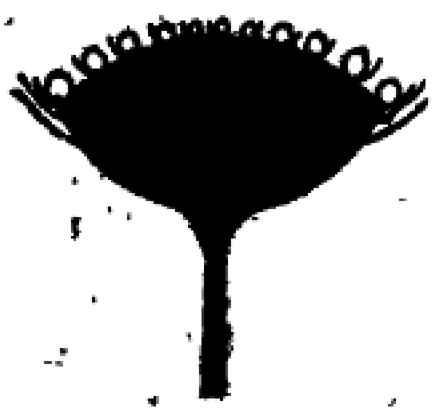
corymb



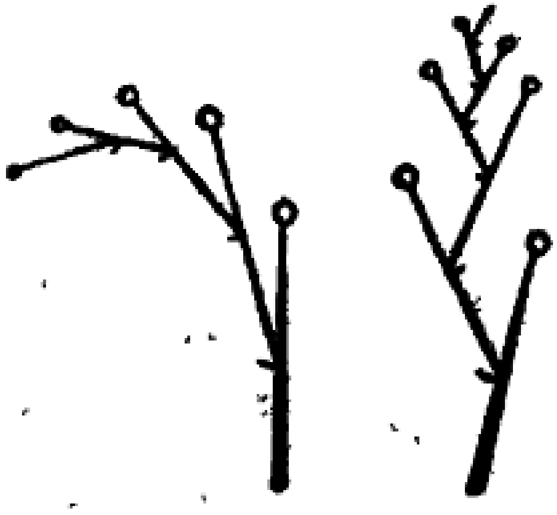
simple umbel



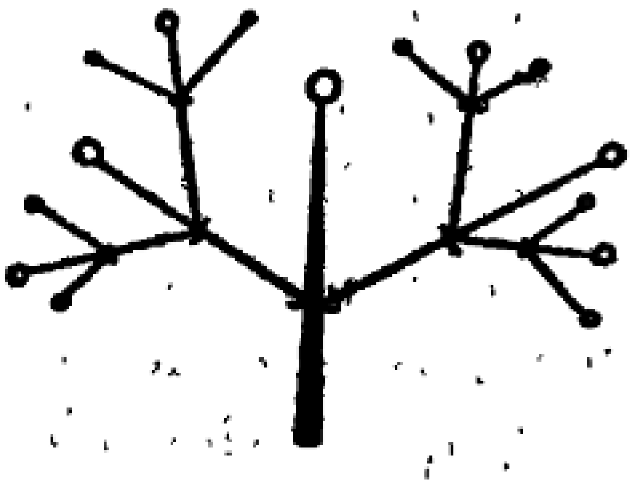
compound umbel



capitulum



monochasium



dichasium

Types of *Cymose* inflorescence.

1. The *cyme,* when the terminal flower opens first and several flowers then open under *e.g.* Jasminum (Juin). The cyme is again divided into several forms according to the number of branches developing below the terminal flower :—

(*a*) If there are two branches, it is called *Dichasium* or Biparous cyme *e.g.,* Teak (Sagoon), Juin or Jasmine.

(*b*) If more than two branches develop it is called *Polychasium e.g.,* Euphorbiaceae.

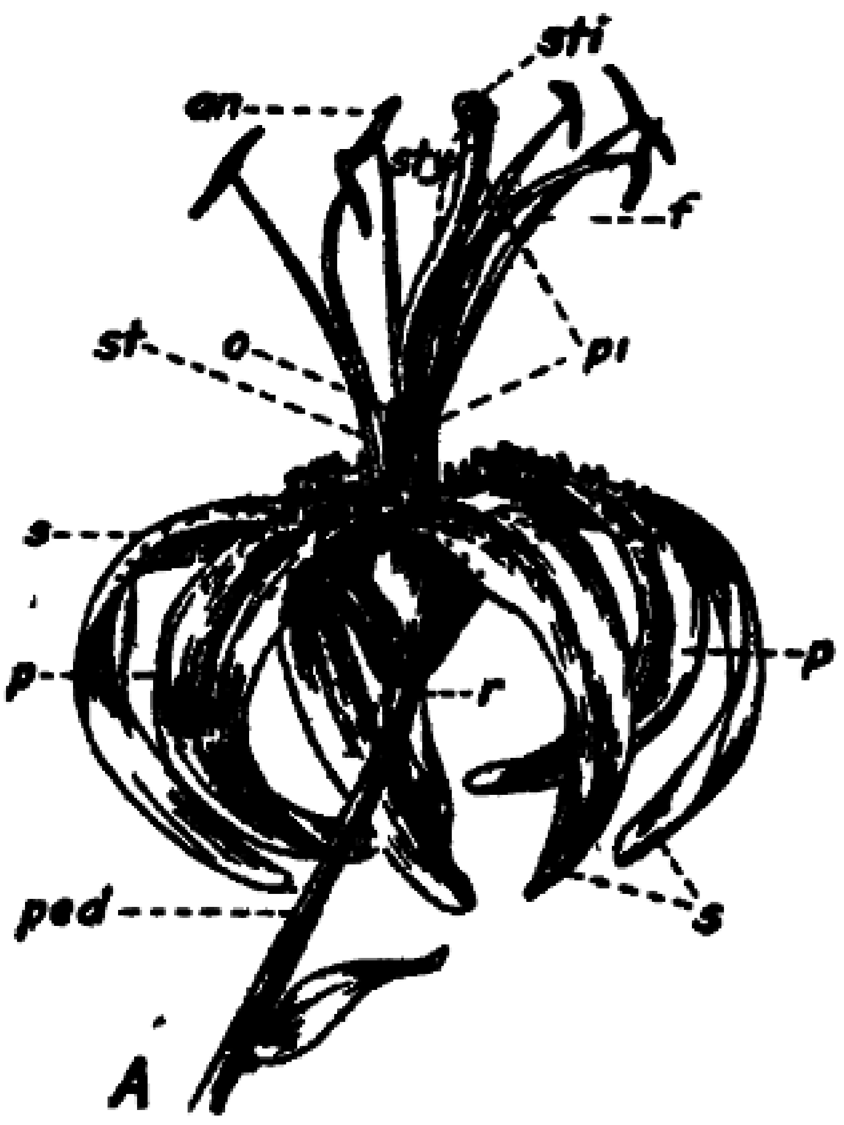
(*c*) If only one branch develops, it is called *Monochasium.* Monochasium may confine their branching to one side when it is called Helicoid *e.g.* Begonia. If the branching be in alternate form it is known as Sorpioid type *e.g.,* (Heliotropium) Hatisur.

2. Cymose umbel is cymose in form but assumes the form of an umbel *e.g.,* Calotropis (Akanda).

3. *Verticillaster* is a cymose type developing in the axils of opposite leaves *e.g.,* Ocimum sanctum (Tulsi).

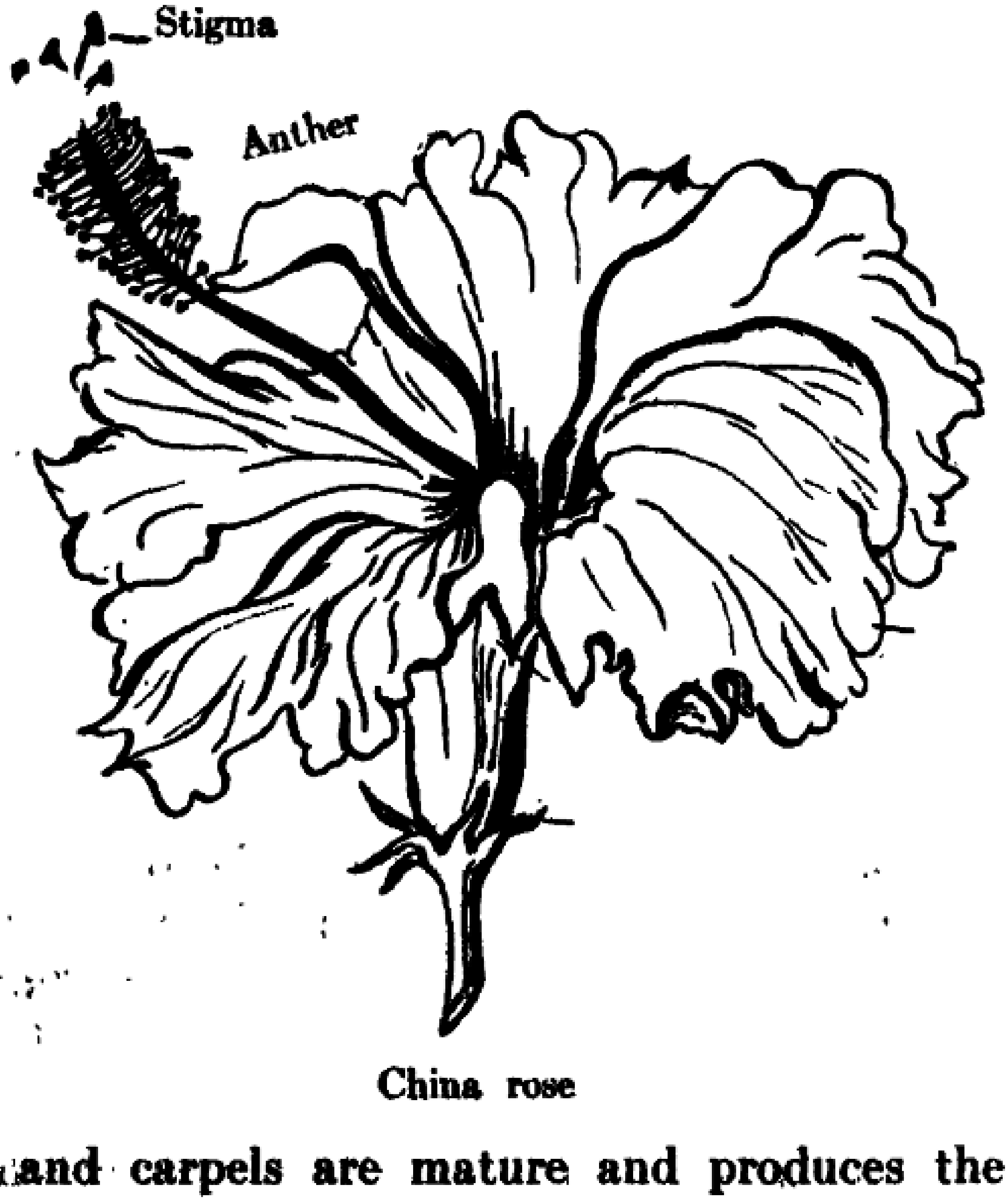
Flower—

A flower is a modified shoot specially adapted for reproduction. Priestley and Scott define *flower as a short shoot axis bearing structures associated with reproduction.* The condensed region of the shoot axis in the flower is described as the receptacle. Functional flowers must contain either stamens or carpels or both, but the term flower is used to cover also certain abnormal forms produced under conditions of cultivation, in which only the inessential parts such as sepals and petals are present and which therefore take no part in reproduction. A flower consists of four whorls *e.g.* **Calyx, Corolla, Andraecium** *and* **Gynoecium.** The individual parts of the first whorl namely the **Calyx,** are the **sepals.** The parts of the second whorl are the **Petals.** The members of the third whorl are the **stamens** and the members of fourth or last whorl are the **Carpels.** The pea flower shows all the four whorls. The axis of the flower on which the floral leaves develop is called the **Thalamus.** Sometimes the end of the peduncle or pedicel in enlarged to which other flower parts are attached and is termed the **Receptacle.** The function of the sepals is regarded as *assimilatory* and a subsidiary function is *protec-*



Ped=peduncle, R=receptacle, S=sepal, P=patal, an=anther, O=Ovary, Pi=pistil, F=filament. Sti=Stigma, Sty=Style, St=Stamen.

tion to more delicate parts of the flower. The sepals are usually green. The petals serve mainly *to attract agents of pollination* which help the flower in attaining the aim for which it is produced by the plant. The Andrœcium produces stamens, the **anthers** of which bear **pollengrains** which are suitably placed on the terminal part of the carpel *e.g.*, the stigma when both stamens and carpels are mature and produces the seed. The stamens and carpels are the most important parts of a flower. The calyx and corolla may or may not be present in a flower but the presence of the Andrœcium or Gynœcium either in the same or different flower is essential for the reproduction of the plant, otherwise they



China rose

run the risk of being annihilated from the surface of the earth. The calyx and the corolla no doubt serve some purpose but that purpose is not the *essential* one. For this the calyx and corolla are regarded as *Helping* or *Non-essential* whorls, whereas the Andrœcium and the Gynœcium on account of their immediate and unavoidable necessity to the plant are regarded as *essential whorls* of a flower.

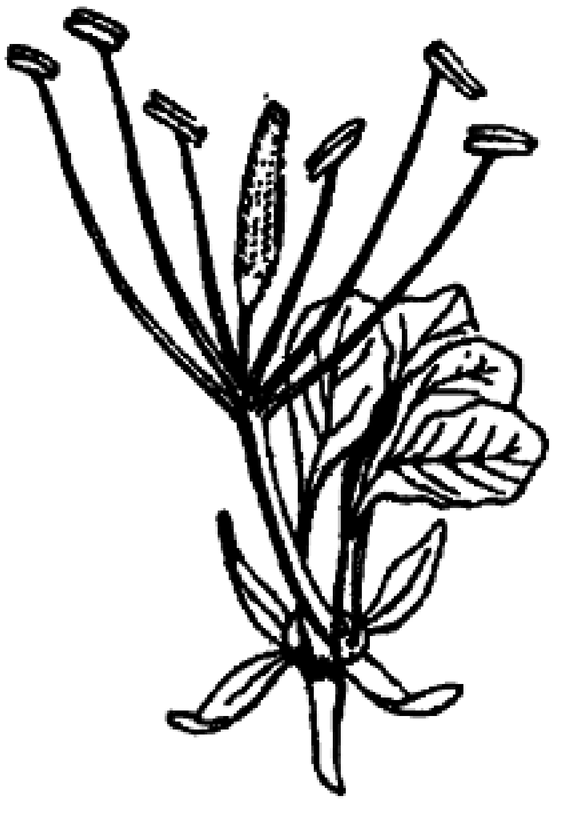
The stamen has a slender stalk called a **filament** and a terminal part called *Anther* which bears the *pollensacs* containing pollengrains. The filament at its terminal part bears a structure called **connective** joining the antherlobes. The carpel consists of a swollen basal part called **ovary** bearing a slender part known as the **style** and the terminal part called the **stigma.** The ovary gets a stimulus on the ovum being fertilised by male gamete produced by pollen-grain and the globular bodies within an ovary known as ovules ultimately form the seeds.

Thus it is found that a flower is a collection of **sporophylls,** either **microsporophylls** or stamens or **megasporophylls** or carpels or both, which are specialised and localised leaves for spore production (microspore or pollen-grain; megaspore or embryosac) and these may or may not he surrounded by accessory sets of floral leaves such as perianth or calyx and corolla. The sporophylls are inserted on a condensed axis called the thalamus and are arranged either in spirals or in whorls. (After Prof. S. N. Banerjee of Calcutta University). In 1676, **Nehemial Grew** first suggested that the stamens and carpels are the male and female organs, respectively of plants. In 1694, **Camerarius** really discovered sex in plants. 150 years after this, the Swedish botanist, **Carl Linnaeus,** accepted the work of Camerarius and made them the basis of classifying the spermatophyta.

The flower is regarded as a modified shoot on account of the following reasons :—

(1) It shows the colour and structure of ordinary foliage leaves in the sepals and petals *e.g.* Water-lily.

(2) The phyllotaxy resembles the ordinary phyllotaxy of leaves. Most flowers show whorled phyllotaxy but spiral arrangement is found in Water-lily, Cactus etc.



Flower of Gynandropsis showing node and internode

(3) Flower buds arise in the axils of bracts.

(4) Nodes and inter-nodes although much suppressed sometimes are distinctly visible *e.g.*, Gynandropsis pentaphylla (Hurhure), Passion-flower (Jhumkolata).

(5) Sometimes the flowering axis after producing the

reproductive organs is continued into a leafy shoot *e.g.*, Pear, Rose.

(6) In some cases as American Alœ, some of the flowers of the inflorescence are modified into leaf-buds called bulbils for vegetative propagation.

Definitions—

When the sepals and petals are not distinguishable from one another, the whorls are known as Perianth. The Monocots usually have a perianth *e.g.*, Tube rose (Rajanigandha). The perianth might have one or more whorls, *e.g.*, Champa (Michelia).

When the four whorls are present in a flower, the flower is said to be **complete.** When one or more of the whorls are absent, the flower is said to be **Incomplete.** When either the Calyx or Corolla is present in a flower, the term **Monochlamydeous** is used *e.g.*, Compositæ.

When both calyx and corolla are present, the flower is said to be **Dichlamydeous** *e.g.*, Rose.

When there is absence of both calyx and corolla, the flower is said to be **Achlamydeous** *e.g.*, Piper betle (Pan).

When both stamens and carpels are present in a flower, it is said to be **Hermaphrodite, bisexual** or **monoclinous.** If either the stamens or carpels are present the flower is said to be **unisexual** or **diclinous.**

Sometimes the flower bears only stamens or carpels, the former is called **Staminate** flower and the latter is known as **Pistillate** flower. The plant is **monoecious** when both staminate and pistillate flowers are borne by the same plant. The plant is **dioecious** if either kind of flowers is borne by a plant *i.e.*, either male or female. If both unisexual and hermaphrodite flowers occur on the same plant, it is said to be **Polygamous** *e.g.*, Mango.

When the sepals and petals are equal in size in their respective whorls, the flower is **regular.** If the size differs among members of the calyx and corolla in their respective whorls, the flower is **irregular.**

If there is a single plane which divides the flower into two equal halves but not more, the flower is said to be **Zygomorphic.**

If there is an indefinite number of planes which can divide the flower into equal halves, the flower is regarded as **Actinomorphic.** When the flower cannot be divided in any plane without losing symmetry, the flower is said to be **Asymmetrical.**

When the sepals, petals, stamens and carpels agree in their number or any multiple thereof, the flower is said to be **Isomerous.** If the number be two or any multiple thereof, the flower is **dimerous,** if three **trimerous,** if four **tetramerous,** if five **pentamerous** and so on.

When there is no agreement in their number, the flower is known as **Anisomerous.**

Usually the flowers are identified from the number of sepals, petals etc. **Trimerous** nature is seen among Monocotyledons while **Pentamerous** form prevails among Dicotyledons. This rule has many exceptions; therefore it should not be much relied upon.

When the flower shows the members to be arranged in the form of whorls, the flower is called **Cyclic** or

whorled, if the members are arranged **spirally** it is known as **Acyclic.** The side facing the stem is known as **Posterior** and the side away from the stem is known as the **Anterior** side of the flower.

Hypogynous. Perigynous and Epigynous flowers—

When the ovary is placed at the top of the thalamus and the sepals, petals and stamens arise below it, the flower is **Hypogynous** and the ovary is superior *e.g.* Lotus, Brinjal, Mustard, Magnolia.

If the sepals, petals and stamens arise round the neck of the ovary, the flower is **Perigynous.** The ovary is here superior *e.g.*, Rose, Pea.

When the sepals, petals and stamens arise from the top of the ovary, the flower is **Epigynous.** The ovary is inferior *e.g.* Sunflower, Guava, Cucumber, Gourd.

Calyx—

The outermost whorl of a flower is known as Calyx. The individual parts of the calyx are known as Sepals. The sepals might be free from one another, when they are known as **Polysepalous.** If the sepals are united to form a tube, they are known as **Gamosepalous.** The number of sepals is made out by counting the number of teeth.

The sepals sometimes fall off as soon as the immediate function is performed, it is then known as **Deciduous.** Sometimes the calyx remains even after the fruit has developed from the flower, it is then known as**Persistent** as in Brinjal, Dillenia (Chalta).

The calyx of the Gamosepalous type may be :—

(1) *Tubular*, when it is tube-like *e.g.*, Datura.

(2) Bell-shaped, when it looks like a bell *e.g.*, China rose (Jaba).

(3) *Hair-like* called Pappus *e.g.*, Sunflower.

Corolla—

The corolla is generally highly coloured *e.g.*, red, yellow, etc., and the individual members are known as **Petals.** Each petal consists of a narrow base known as **Claw,** and a broad upper part known as the **Limb.** The petals when united are known as **Gamopetalous,** while the petals when free are known as **Polypetalous.**

The **polypetalous** corolla may be :—

(1) **Rosaceous,** when the petals have small or no claw *eg.*, Rose, Tea.

(2) **Cruciform,** when four petals are arranged in the form of a cross *e.g.*, Radish, Mustard.

(3) **Papilionaceous,** when the petals are irregular, five in number, and one of which is larger than others. The largest petal is posterior and is called the **Vexillum** or **standard.** The two petals situated at the sides are known as **Alae** or **Wings.** The two petals situated anteriorly form a boat-shaped structure called **Keel** or **Carina** *e.g.*, Pea, Papilionaceae, Bean, Clitoria (Aparajita).

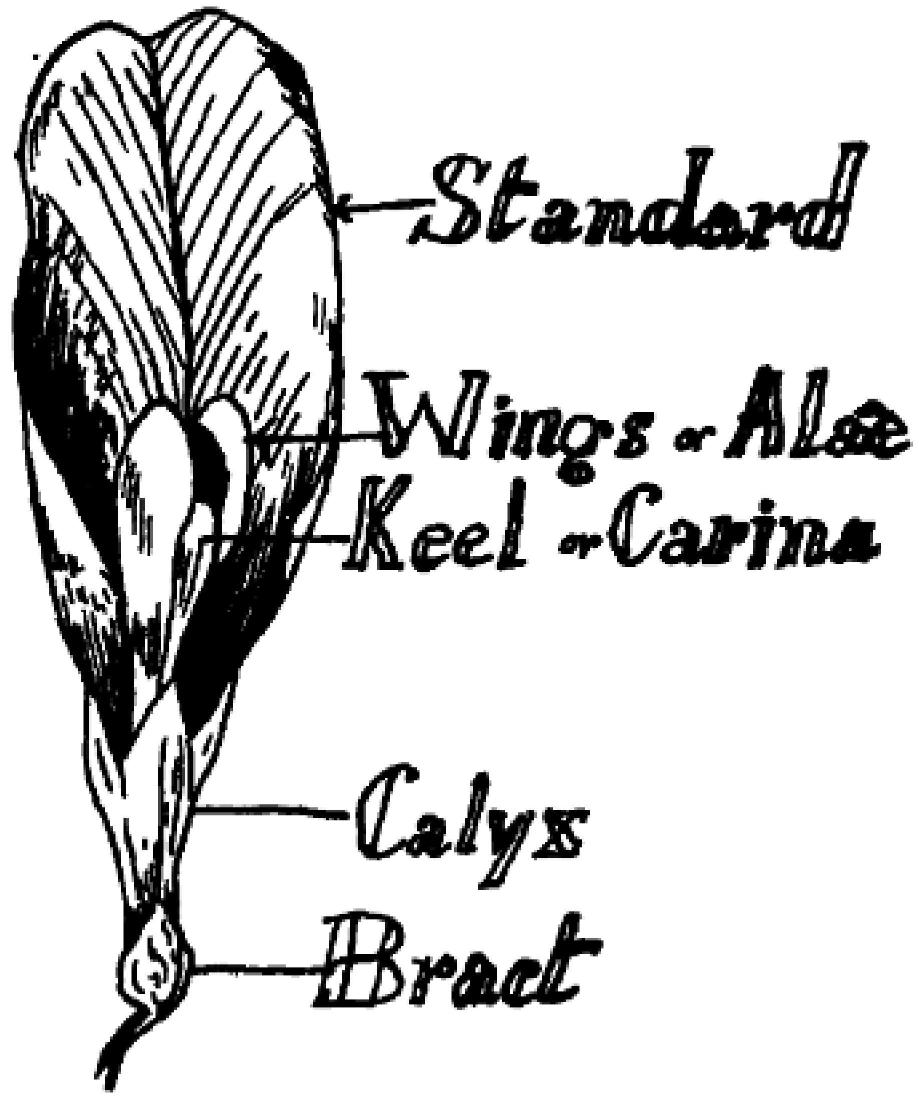
Gamopetalous corolla may be :—

(1) **Tubular,** when the petals form a tube. *e.g.*, florets of Sunflower.

(2) **Campanulate** or Bell-shaped *e.g.*, Swarnolata, Gooseberry (Tepari).

(3) **Rotate,** if the tube is short but the limbs are spreading *e.g.* Brinjal, Periwinkle (Nayantara), Night jasmine (Shephalika).

(4) **Labiate** or **Bilabiate,** when the petals are irregular and generally form a two-lipped structure *e.g.*, Ocimum (Tulsi), Leonurus (Drone).



Flower with papilionaceous corolla.

(5) **Infundibuliform** or funnel-shaped when the corolla is shaped like a funnel *i.e.*, gradually spreading outwards from a narrow base as in Datura (Thornapple), Water bindweed (Kalmi-sak).

(6) **Personate** or masked where the corolla is two-lipped but the lips almost touch at the throat of the corolla as in Lindenbergia (Basanti).

(7) **Ligulate** or strap-shaped when the corolla is flattened and strap-like as in the ray florets of Sunflower.

Corona—

Sometimes the throat of the corolla shows an outgrowth of scales, lobes or hairs, which are called **Corona** as in Passion-flower, Oleander (Karabi).

CHAPTER XVI

AESTIVATION.

The arrangement of petals and sepals in a flowerbud is called **Aestivation** as compared with Vernation which is an arrangement of foliage leaves in a bud. They may be :—

(1) **Valvate**—when the sepals or petals lie very close but do not overlap as in Custard apple (Ata), Lemon, Artabotrys (Kantali-champa).

(2) **Imbricate**—when the margins overlap each other *e.g.*, Poppy, Cassia (Kalkasunde).

(3) **Vexillary**—when the vexillum encloses other petals in a papilionaceous corolla *e.g.*, Pea, Bean.

(4) **Twisted**—as in China rose, Cotton.

Andraecium—

The collective name of the stamens is **Andraecium.** The stamens contain within them the **pollen-grains** or **microspores** which ultimately bring about certain drastic changes leading to the production of seed. Each **stamen** has three distinct parts *e.g.*, a fine slender stalk called **Filament,** a knoblike head called **Anther** bearing two lobes. Each lobe contains two **pollensacs** carrying a number of **pollengrains.** The two lobes of the anther are connected by a structure called the **connective.**

The attachment of the filament to anther may be in the following forms :—

(1) **Dorsifixed,** when the filament is attached to the connective at the back of anther *e.g.,* Passion-flower.

(2) **Basifixed.** when the filament is attached at the base of anther *e.g.,* Mustard, Waterlily.

(3) **Versatile,** when the anther freely moves to and fro at the end of the filament *e.g.,* Grass, Spider Lily (Crinum).

(4) **Adnate,** when the filament runs from the base to the apex of the anther *e.g.,* Michelia (Champa).

Definition —

The union of similar parts is known as **cohesion** *e.g.,* stamen with stamen. The union of dissimilar parts is known as ***adhesion*** *e.g.,* petal with stamen.

The stamens are usually free but sometimes they cohere with one another. The stamens may form one bundle when they are called **Monadelphous** *e.g.,* China-rose. If they form two bundles, they are known as **Diadelphous** *e.g.,* Pea. If they form more than two bundles they are called **Polyadelphous** *e.g.,* Orange, Castor oil.

When the cohesion is confined to the anthers, the filaments remaining free, the condition is known as **Syngenesious** *e.g.,* Sunflower.

If there are four free stamens in a flower of which two are long and two are short, they are known as **Didynamous** *e.g.,* Ocimum (Tulsi), Labiatæ.

When the number of stamens is six of which four are long and two are short, they are known as **Tetradynamous** *e.g.*, Mustard, Cruciferæ.

If the stamens adhere to the corolla tube as if they arise from the petals, they are known as **epipetalous** *e.g.*, Datura. If the stamens unite with the pistil, it is **gynandrous** *e.g.*, Calotropis (Akanda).

When the anthers are ripe, the pollengrains come out by bursting the anther in various ways :—

(1) By valves *e.g.*, Tejpat, Cinnamon.

(2) By pores *e.g.*, Brinjal, Potato.

(3) Longitudinally *e.g.*, Shoeflower, Datura.

Gynoecium or **pistil** —

The gynoecium or pistil is the collective name of the last whorl of a flower. The pistil may be composed of a single carpel or a number of carpels. The pistil has got three parts, a more or less swollen basal part called the **Ovary,** a tube-like middle part called the **Style** and a sticky upper part called **Stigma.** The female cell is situated inside a globular body called **Ovule** attached to the ovary. There may be a single ovule inside an ovary or a number of ovules. The pollen-grain comes to lie on the stigma and then it passes by means of a tube to the ovule. Inside the ovule, we get the female cell called **Oosphere** or **Ovum.**

When the ovary is composed of a single carpellary leaf *i.e.*, when the margins of a carpellary leaf unite to form the ovary, it is known as **Monocarpellary.** The margins unite to form the **ventral suture** and the corresponding midrib forms the **dorsal suture.** The chamber is called the **Loculus** or **cell.**

If there is a single carpel and the ovary is formed by the margins uniting to form a chamber, it is called **Apocarpous** (single) gynoecium. If the carpels remain separate in a multicarpellary ovary, it is known as **Apocarpous** (Multiple) gynoecium *e.g.*, Rose, Lotus.

When the carpels instead of remaining separate unite to form a single structure, it is known as **Syncarpous** as China rose.

The syncarpous ovary may be composed of two, three, four etc., and are accordingly termed **bicarpellary, tricarpellary** etc. If the carpels unite by their margins, then the central chamber is single but the margins might project inside the chamber to divide it into two, three etc. **loculi.**

Placentation —

The ovules remain attached inside the ovary by a **special tissue** which is known as **Placenta.** The arrangement of the placenta is known as **Placentation.**

It may be :—

(1) **Parietal,** when the ovary is syncarpous (two or more carpels) and the ovules arise from the united carpellary margins *e.g.*, Gourd, Mustard, Poppy, Papaw.

(2) **Marginal,** when the ovules arise from the margins of a monocarpellary ovary *e.g.*, Pea, Bean.

(3) **Axile,** when the margins inside a syncarpous ovary approach the central axis dividing the ovary into

several chambers and then the ovules appear to develop from the central axis. Such placentation is called Axile *e.g.*, Lemon, Orange, China rose (Jaba), Potato.

(4) **Free-central,** when the partitions in a syncarpous ovary disappear and the ovules arise from the central column *e.g.*, Pink flower.

(5) **Basal,** when there is a single erect basal ovule arising from the terminal point of the thalamus *e.g.*, Sunflower.

(6) **Superficial,** when the placentæ develop all round the inner surface of ovary *e.g.*, Water-lily.

Forms of ovules —

The study of the forms of ovules may be preceded by a brief description of the structure. The stalk of the ovule is known as the **funicle. Hilum** is the point of attachment of the stalk of the ovule. The tissue which is found inside the ovule is known as **Nucellus** and the covering of the ovule is in the form of two **integuments.** There is an opening at the apex of the ovule which is called the **micropyle.** At the base of the nucellus and the integuments, the structure which is not clearly distinguishable is known as the **chalaza.** There is a large structure embedded in the nucellus towards the micropylar end called the **Embryo-sac.** The embryo-sac gradually develops by division of the nucleus—8 nuclei which collect cytoplasm and form 7 naked cells. Towards micropyle, three cells are found called the **egg-apparatus;** one of which is the female gemete called the **ovum** or **oosphere** (egg-cell) and the other two are the **synergidae** or helping cells. Three cells lie opposite the micropyle called the **antipodal** cells. In the middle of the embryo-sac, the remaining two nuclei fuse to form the **Secondary nucleus.**

Ovules may be :—

(1) **Atropous** or **Orthotropous,** when the micropyle, funicle and the chalaza, all lie in the same straight line *e.g.,* Pine, Betel (Pan).

(2) **Anatropous,** the funicle runs parallel with the inverted ovule *i.e.*, the chalaza and the micropyle lie in the same straight line and the ovule is situated by the side of the funicle *e.g.*, Bean.

(3) **Campylotropous,** if the ovule curves and the micropyle and the chalaza are not placed in the same line *e.g.,* Krisnakali, Mustard.

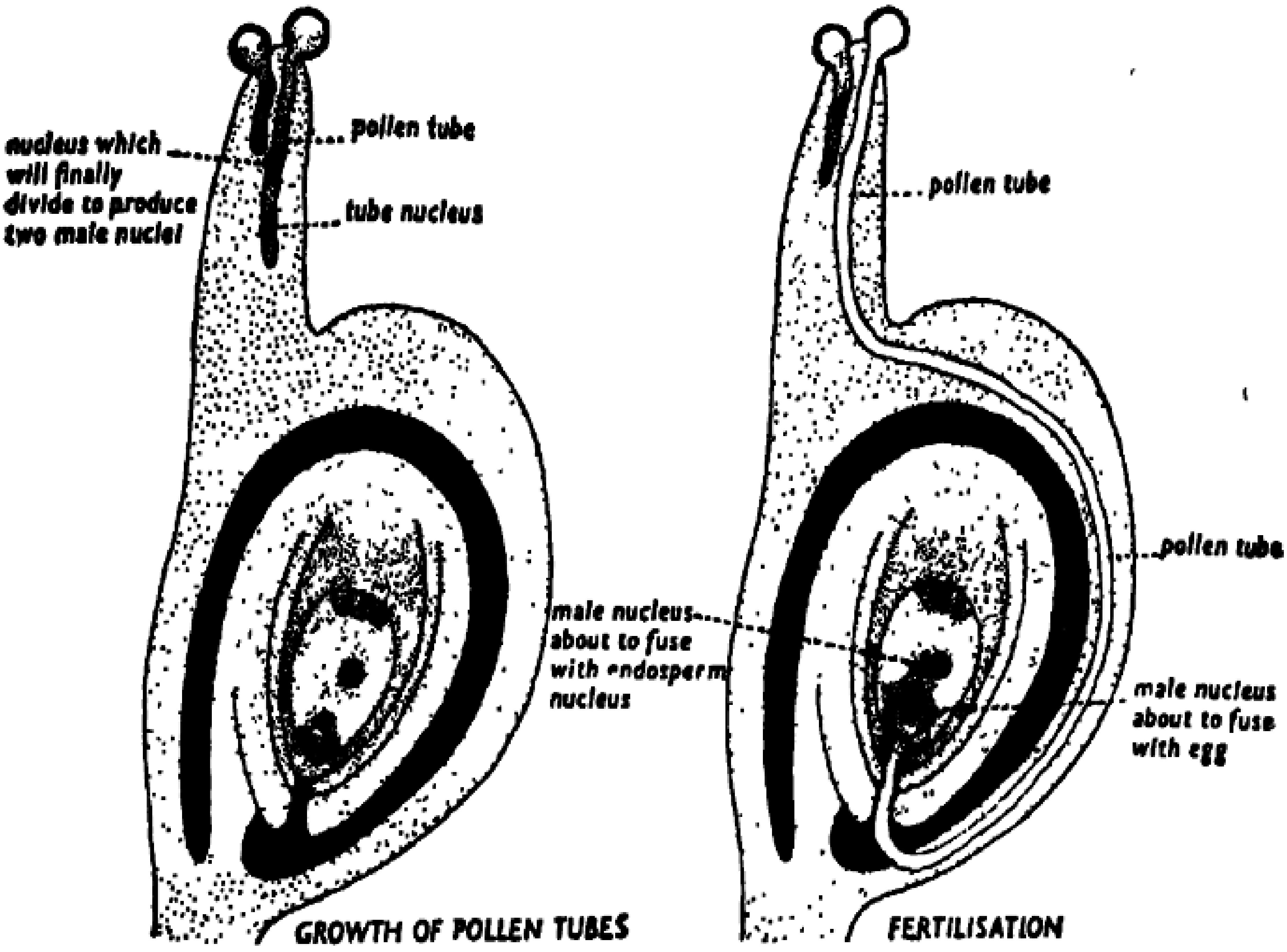
(4) **Amphitropous,** when the ovule is at right angles to the funicle and the chalaza and the micropyle lie in the same line *e g.,* Poppy.

Pollination and Fertilization -

The transfer of the mature pollen-grains from the anther to the surface of the stigma is known as **pollination.**

Pollination is effected by various ways. Pollination is essential for a flower because the production of seed is dependent on this transfer. The pollen-grain when transferred to the stigma sends out a tube which carries within it, the **male cell** to fuse with the **female cell** lying within the ovule.

When the pollen-grain of the same flower is pollinating the stigma, the process is known as **self-pollination.** If the pollen of one flower pollinates the stigma of another flower of the same species, the process is known as **Cross-pollination.** As the pollination is directly concerned with the production of seed, certain essential changes proceed in the interval. The male cell unites with the female cell and this process of union is known as **fertilization.**


nucleus which will finally divide to produce two male nuclei
pollen tube
tube nucleus
pollen tube
pollen tube
male nucleus about to fuse with endosperm nucleus
male nucleus about to fuse with egg

GROWTH OF POLLEN TUBES

FERTILISATION

Self-pollination and Cross-pollination —

There are advantages and disadvantages in both the processes. In self-pollination, the characters of the identical flower are perpetuated *i.e.*, the same conditions are available for the plant. The advantage is that the chance is very great for pollination. In cross-pollination the characters of different individuals are available so that the future plants are much more healthy and strong. The disadvantages are that a considerable portion of the material of the plant is spent to make room for adopting contrivances namely colouration of the flower etc. and the chances of pollination become remote. If for any reason, the pollinating agents fail to discharge the pollen on the stigma.

Pollen-grains cannot move by themselves so that in cross-pollination, they have to be carried by different agents namely water, wind, insects, birds etc.

Flowers that are pollinated by insects, are known as **entomophilous** flowers *e.g.*, Shoeflower (Jaba), Lotus.

Flowers which receive the pollen through water are known as **hydrophilous** *e.g.*, Vallisneria.

Flowers which are pollinated through wind are known as **Anemophilous,** *e.g.*, Grass. Flowers that are pollinated by birds are known as **Ornitho-philous** *e.g.*, Silk-cotton tree (Simul).

The next step after the deposit of pollen is fertilization. The union of male cell or gamete with female cell or gamete results in fertilization. The **fertilization** gives a stimulus which is shown by activity of the surrounding parts namely the changes undergone by the ovary. In the higher plants such as Angiosperms, the pollen-grain germinates on the stigma and sends out a tube-like structure carrying within it the male gamete and finally passes through the style to the micropyle of the ovule.

The ovule contains within it the female gamete or oosphere besides other cells which serve as guiding structures. The male gamete unites with the oosphere to form the oospore. The oospore gradually develops into an embryo.

The ovules after fertilization become the seeds enclosed in the case called the fruit. The other structures namely the sepals, petals and stamens generally wither away. Occasionally however, some parts might grow with the fruit.

CHAPTER XVII

FRUIT.

The **Fruit** is derived from the ovary as a result of fertilization of ovule.

The fruit may be formed from the ovary only or other parts of the flower may take part in its formation. There are two kinds of fruits, those that are derived from the ovary only are known as **True fruits** *e.g.*, Mango. Those that are derived from the ovary together with some other parts are known as **False fruits** *e.g.*, Pineapple, Rose, Dillenia (Chalta).

Sometimes fruits are fleshy. The wall of the fruit is known as **Pericarp.** The pericarp shows different layers and in mango, the pericarp is differentiated into three parts. The uppermost skin-like part is known as **epicarp.** The middle fleshy part is called the **mesocarp.** It is fibrous in cocoanut and forms fleshy edible portion in mango. The hard stone within is known as **endocarp.**

Fruits are classified into three classes:—

(1) **Simple,** (2) **Aggregate** and (3) **Collective** or **Multiple.**

Simple fruit is generally derived from a single ovary with one carpel or from syncarpons multicarpellary ovary.

(2) Aggregate fruit is derived from a single ovary with apocarpous pistil.

(3) Collective fruit is formed from a group of flowers and other parts might grow with the fruit.

Simple fruits —

Simple fruits are divided into two groups :—

(1) *Dry fruits,* in which the pericarp is dry and membranous.

(2) *Succulent fruits,* in which the pericarp is fleshy.

Dry fruits may be :—

(*a*) **Indehiscent,** where the pericarp does not rupture to disperse the seeds.

(*i*) **Achene,** one-seeded and the fruit arises from a superior ovary and the pericarp is membranous *e.g.,* Clematis (Chagalbati), Sunflower.

(*ii*) **Caryopsis,** one-seeded and the fruit arises from a superior ovary but the pericarp and testa are closely attached *e.g.,* Paddy (Dhan), Wheat, Barley, etc.

(*iii*) **Samara,** one or two-seeded; pericarp bearing a wing-like outgrowth *e.g.,* Shorea (Sal), Hiptage (Madhabi-lata).

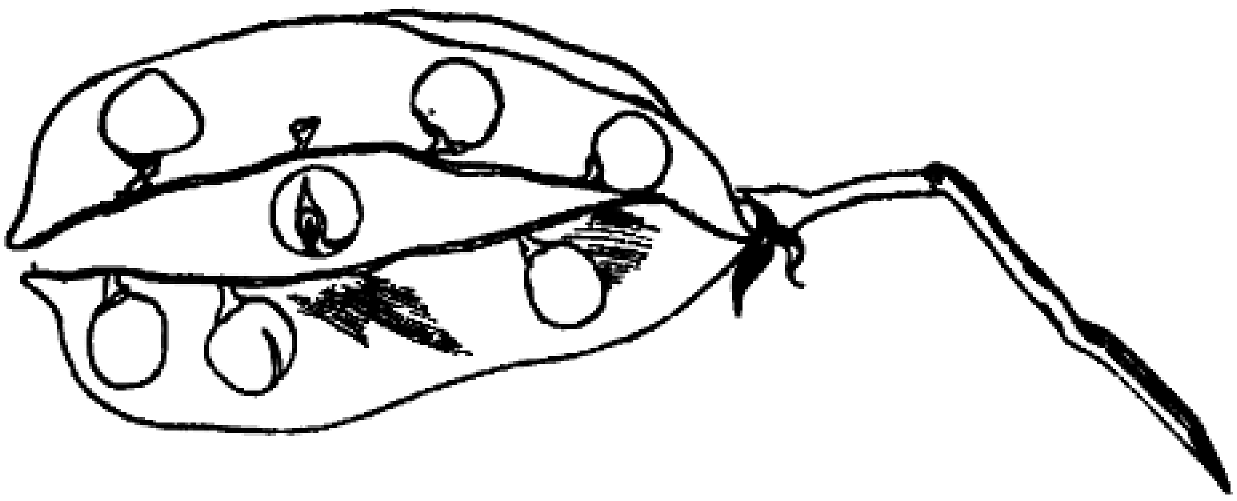
(*iv*) **Schizocarp,** carpels two or more; united *e.g.,* Carrot.

(*v*) **Nut,** a hard, one-seeded fruit, generally from a compound ovary *e.g.,* Oak.

(*b*) **Dehiscent,** when the pericarp bursts down to distribute the seeds.

(*i*) **Follicle,** the fruit consists of a single carpel and the dehiscence takes place along the ventral suture *e.g.,* Nerium (Karabi), Michelia champaca (Champa), Periwinkle (Nayantara).

(*ii*) **Legume or pod,** the fruit is monocarpellary but dehisces from both ventral and dorsal sutures *e.g.*, Pea, Bean.



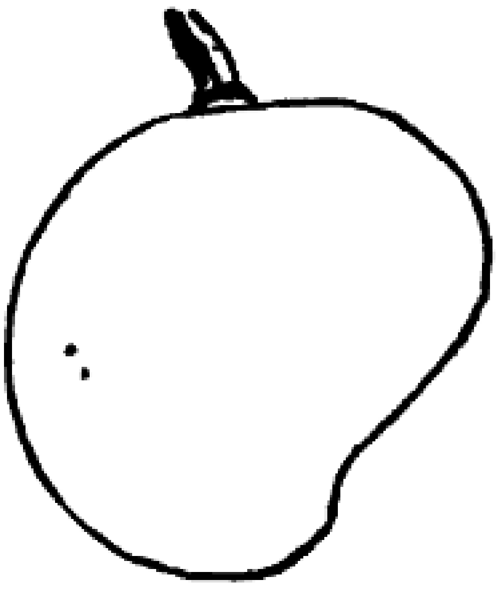
Legume—Pea.

(*iii*) **Capsule,** the fruit is derived from a syncarpous ovary *e.g.*, Cotton, Datura.

(*iv*) **Siliqua,** dry, long, fruit derived from superior bicarpellary ovary. It dehisces from below upwards *e.g.*, Mustard.

Fleshy or **Succulent fruits**—

Succulent fruits are generally with a pulpy mass and differentiated into three more or less distinct layers. They do not dehisce.



Drupe—Mango.

(*i*) **Drupe,** the fruit shows a fleshy pericarp having a thin outer epicarp, a succulent mesocarp and a hard endocarp. It is one-seeded and derived from a single carpel *e.g.*, Mango.

(*ii*) **Berry,** the ovary—wall is fleshy and encloses one or more carpels and seeds *e.g.*, Grape, Tomato, Date, Plantain, Brinjal.

Berry—Brinjal

(*a*) **Pepo,** the fruit is a berry with hard rind *e g*, Cucumber, Gourd, Water-melon (Tarmuj).

(*b*) **Hesperidium,** a type of berry with a leathery rind *e.g.*, Orange, Lemon.

(*iii*) **Pome,** it is derived from several carpels; receptacle is fleshy; outer portion of pericarp is fleshy and the inner portion is papery *e.g.*, Pear, Apple.

Aggregate fruits—

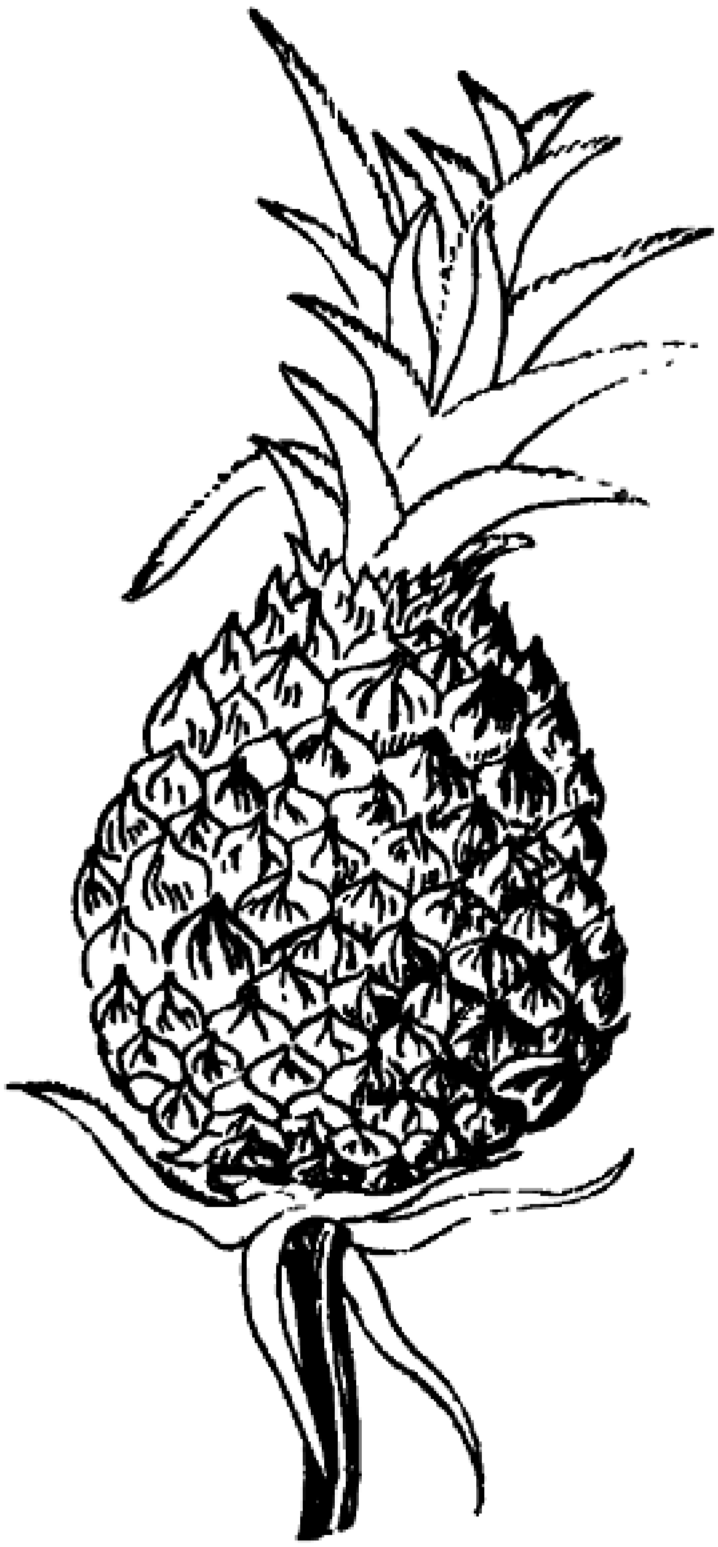
The aggregate fruits are derived from apocarpous pistils. The fruits are so to say collection of simple fruits. The term etaerio is used for them. Thus there may be etaerio of achenes, drupes, follicles; rose, lotus etc.

Collective fruits or **Multiple fruits**—

Sometimes the whole inflorescence may be converted into a single fruit. It is also called an **Infructescence.**

(*i*) **Sorosis,** the whole inflorescence with the fleshy axis is converted into a single fruit *e.g.*, Jack-fruit (Kantal), Pineapple.

(*ii*) **Syconus,** when the jug-shaped thalamus bearing a number of flowers, is converted into a fruit *e.g.*, Fig, Banyan.



Pineapple—Sorosis

(*iii*) **Cone,** when the scales also take part in the formation of the fruit and looks like a cone *e.g.*, Pine.

Dispersal of fruits and seeds —

The fruits and seeds require that distribution should take place in as far lands as possible. There are various ways whereby such distribution is helped. Plants distribute their seeds in order to prevent congestion of too many plants in a limited area. The means adopted by plants are :—

(1) *Wind*, (2) *Animals*, (3) *Water* and (4) *Human agency*.

Wind,—the plants which distribute their fruits and seeds through wind either develop wing-like outgrowths or bear pappus or develop hairs. Fruits of Hiptage (Madhabilata) develop wings, the sepals of Shorea (Sal) act as wings in fruits ; seeds of horse-radish (Sajina) have wings.

Animals,—sometimes seeds adhere to animals either through some hook-like structures or they may eat the fruits without digesting the seeds which in the meantime are carried to a distance and when the seeds leave the alimentary canal, are more fit to germinate *e.g.*, Plum, Banyan and Date-palm are distributed in the above manner.

Water,—current of water carries the seeds to long distances and ultimately deposits the seeds to grow on the shore *e.g.*, Cocoanut.

Human agency,—human beings take fancy over certain fruits and carry them to long distances and thus help in the distribution of seeds.

CHAPTER XVIII

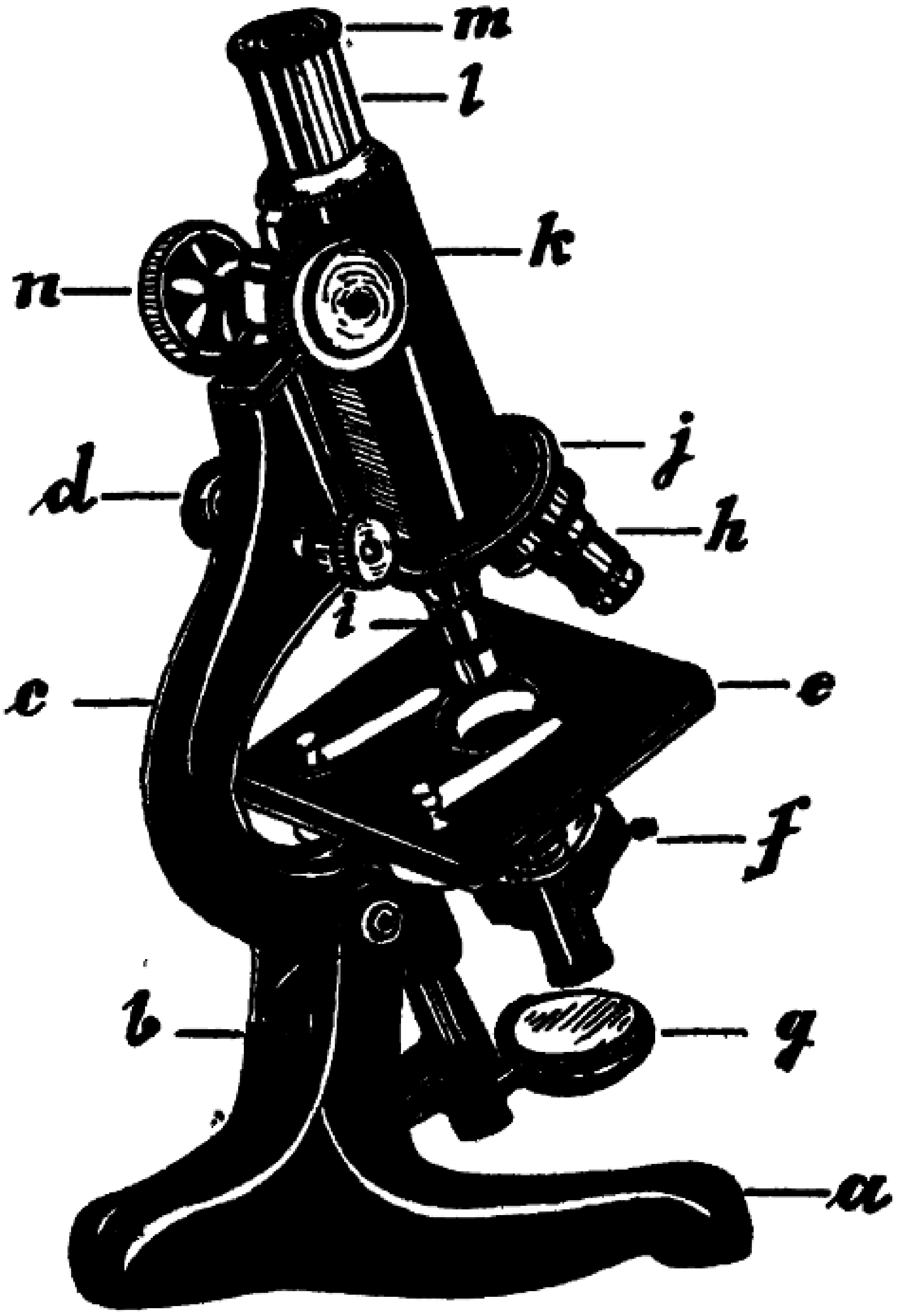
HISTOLOGY OR ANATOMY OF PLANTS.

The Vegetable Cell—

The study of plants with the help of a special instrument called **microscope** revealing the minute structure is called **histology.** There are very minute units which group to form the body of a plant. Ordinarily, a thin slice from any part of a plant when placed under the microscope shows that there are brick-like structures which are known as **cells.** Plants may be composed of a single **cell** or a number of cells. Plants like the rose are composed of millions of cells. A single cell might perform all the duties performed by different organs of a highly developed plant like the pea or maize. Protococcus and Pleurococcus are examples of unicellular plants.

Vegetable Cell—

The **cell** of a plant generally shows a definite limiting membrane called **cell-wall** enclosing within it a bit of living matter called **protoplasm.** The protoplasm is a general name which includes all structures found within the cell-wall. There is a highly specialised body called the **nucleus.** The nucleus is generally placed at the centre of a cell. The mass of protoplasm outside the nucleus is known as **cytoplasm.** There are some round bodies in the cytoplasm called **plastids.** According to recent researches, food is stored up inside the cells from the very beginning which may be in the liquid form in special small cavities called **vacuoles.** The vacuoles are filled with cell sap. The older theory was that vacuoles are formed in old cells as a result of active growth. Some special bodies called mitochondria are found in the cytoplasm in the form of rods. Special stains reveal a net-like structure of yet another minute body in the cell



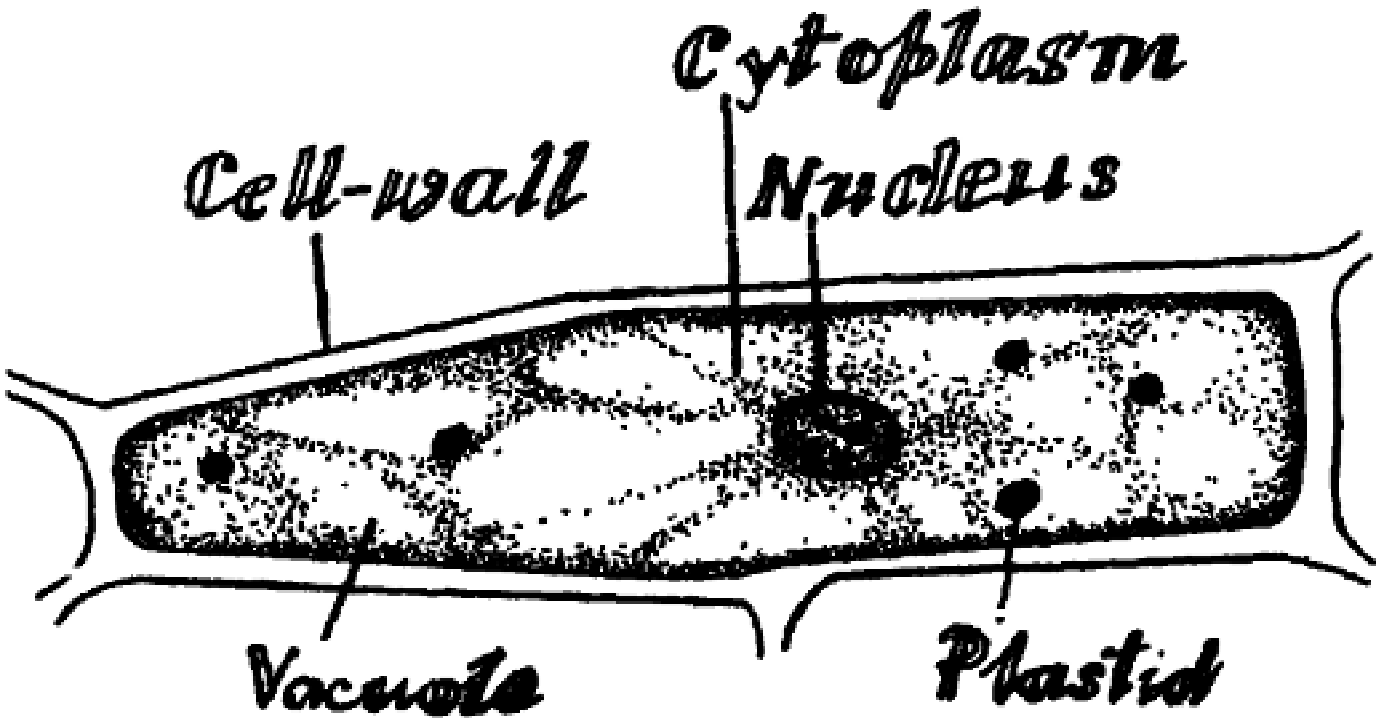
a=foot,
b=pillar,
c=limb.
d=fine adjustment screw,
e=stage,
f=condenser.
g=mirror.
h=objective.
i=objective.
j=nosepiece.
k=body-tube.
l=draw-tube.
m=eye-piece.
n=rough adjustment.

Compound Microscope.

called the Golgi-body. The presence of golgi-body has recently been disputed.

Therefofe a **typical plant—cell** has a definite cell-wall, nucleus, cytoplasm, plastids, mitochondria, golgi-body and vacuoles.

Vegetable cell



The cells are regarded as the structural and functional units of the plant-body.

The living cell-contents—

Protoplasm (protos=first; plasma=anything formed. See Chapter II, page 7).

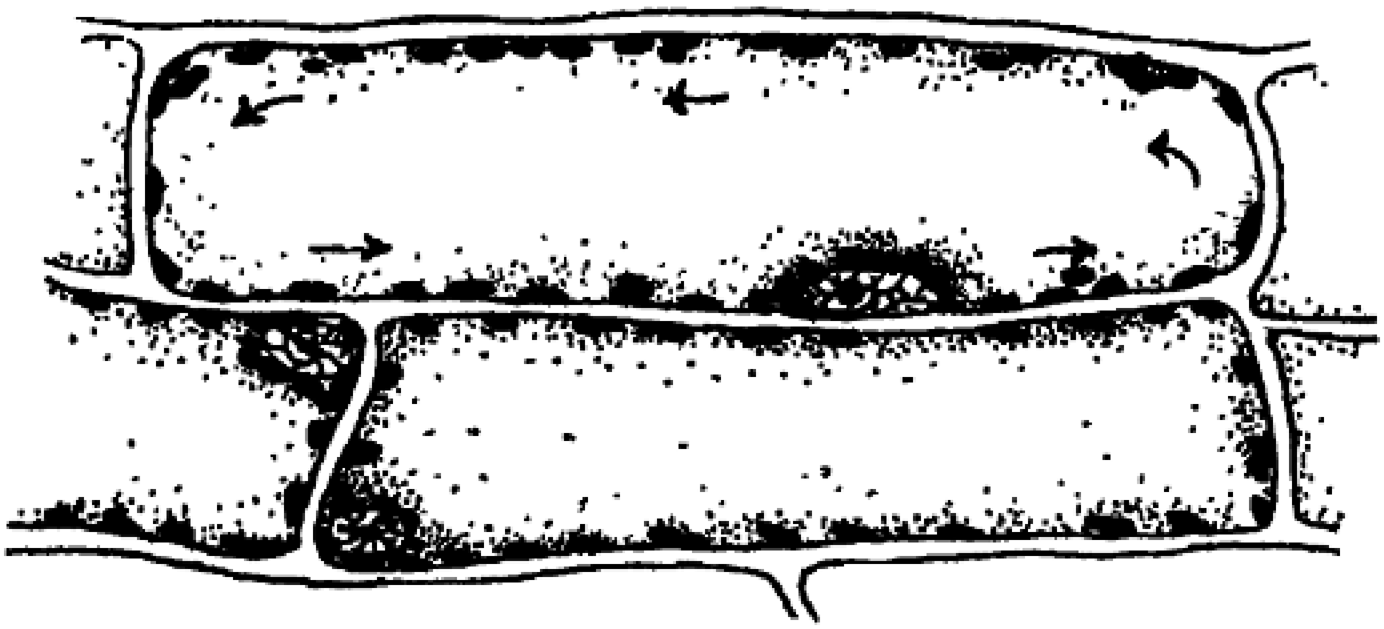
A unit or independent mass of protoplasm as found in a cell, is known as the **Protoplast** and is differentiated into (*a*) **cytoplasm,** (*b*) **nucleus** and (*c*) **plastids.**

The term protoplasm was used by a human physiologist named Purkinje in 1840 for the granular substance of the animal ovum. In 1844, Von Mohl designated the living substance of the plant-cell as protoplasm. Between 1844 and 1855, the identity of plant protoplasm and animal protoplasm was established.

Plastids—

These are spherical bodies found in the cytoplasm of vegetable cells. They are living structures and are always formed by division from the pre-existing ones. Plastids are absent in fungi. There are three types of plastids *e.g.,* (1) **Chloroplastid** or **Chloroplast** or green plastid, (2) **Chromoplastid** or **Chromoplast** and (3) **Leucoplastid** or **Leucoplast.**

(1) **Chloroplastid**—These are found in green parts of plants. The green colour called **Chlorophyll** is stored in the plastid and hence the name. It is essential for the purpose of photo-synthesis. Chlorophyll is associated with two other pigments called **Xanthophyll** (yellow) and **Carotin** (orange-red). The movement of cytoplasm is evident from the plastids of Vallisneria leaf. Really the plastids do not move but the medium *e.g.,* cytoplasm is moving.



Rotation

(2) **Chromoplastids** or **chromoplasts**—These bodies are generally found in the coloured parts of plants specially the petals of flowers. They contain various colours *e.g.,* yellow, red etc.

(3) **Leucoplastids** are colourless (white) plastids and are generally found in parts not exposed to light *e.g.,* underground stems and roots. They convert sugar into starch. The plastids are formed from other plastids (division) which were already in the cells.

CHAPTER XIX

NUCLEUS.

The **nucleus** is the highly differentiated structure in a cell. It is more or less round. The nucleus has a wall called nuclear membrane. The central part of the nucleus shows one or more round bodies called **nucleoli.** Its structure is net-like and is called **nuclear reticulum** consisting of threads called linin. The whole structure found within the nucleus is called **nucleoplasm.** In the nucleoplasm, there are empty cavities filled with **nuclear sap** and are called nuclear sap cavities.

Generally, a cell has a single nucleus which is known as uninucleate condition but there are cells which have more than one nucleus which are called multi—nucleate cells. If a nucleus divides and forms several nuclei without developing partition—walls *i.e.,* if a single cell has many nuclei it is called a **coenocyte.** In some reproductive cells, multi—nucleate condition is found.

The composition of nucleus is similar to protoplasm *i.e.,* almost all the elements are found common to both and an additional amount of phosphorus is found in the nucleus.

Function of nucleus—

Nucleus is the most important structure in a cell. It directs all the activities of the cell. Nucleus has got some structures within it, called **chromosomes** which are visible when the cell divides and which are endowed with the property of carrying **hereditory characters.**

Test for nucleus—

- Iodine solution stains nucleus deep brown.

The cell-wall—

Every vegetable cell has a wall composed of a substance called cellulose although there are some cells which are naked *i.e.*, without wall in the reproductive stage of plants. The cell wall is regarded as a non-living structure as opposed to nucleus and cytoplasm which are living structures of a cell. The cell—wall is a secretion of the protoplasm. It is permeable to water. Cell wall has a very important work to do, it preserves the shape of the cell. The cell wall thickens in various ways :—

(*a*) **Apposition**—new particles of cellulose are deposited on the old wall in succession.

(b) **Intussusception**—sometimes particles are deposited inside the old membrane.

(*c*) **Superposition**—when there are layers of cellulose deposit.

Composition of cell-wall—

Cell-wall is composed of a substance called cellulose which belongs to the group of carbohydrates, a near relative of starch. The formula is $(C_6H_{10}O_5)$ n. Cellulose is the substance generally forming the wall of all higher plants but there is another substance called **chitin** which forms the cell-wall of plants belonging to the group of **Fungi.**

Tests for cellulose.

(*a*) Treat a piece of cotton wool which contains cellulose with iodine and sulphuric acid, it swells up and turns blue.

(*b*) Chlor-zinc—iodine gives it a violet colour.

The thickening of the cell-walls takes place not uniformly but generally thin portions are left out for the entry of water and other dissolved substances. The cells become rigid as a result of such thickening and assist the plant to withstand all sorts of pressures *i.e.*, they become mechanical tissues of the plant. The cells lose their protoplasmic contents and are dead.

The cells thus assume various forms and are said to be :—

(*a*) **Annular**—when the thickenings are in the form of rings.

(*b*) **Spiral**—when it assumes the form of a spiral.

(*c*) **Reticulate**—when the thickenings by joining with one other, assume the form of a net.

(*d*) **Scalariform**—when the thickenings assume the forms of a ladder.

(*e*) **Pitted**—when cavities are left by thickenings spread over almost the whole surface.

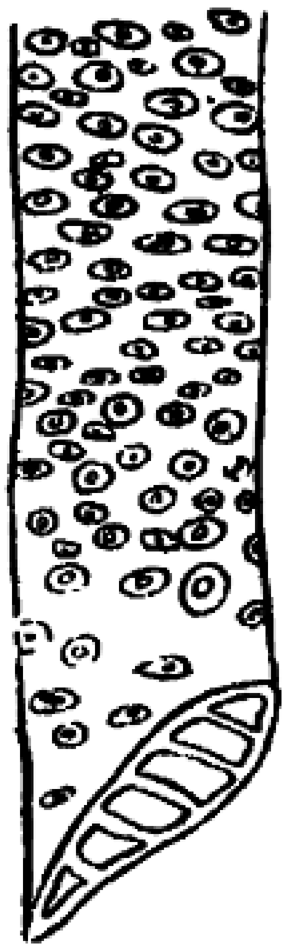
The pits often assume the form of two concentric circles when seen from the surface. A circular area of the wall remains unthickened. Such thickenings are known as **Bordered** pits.

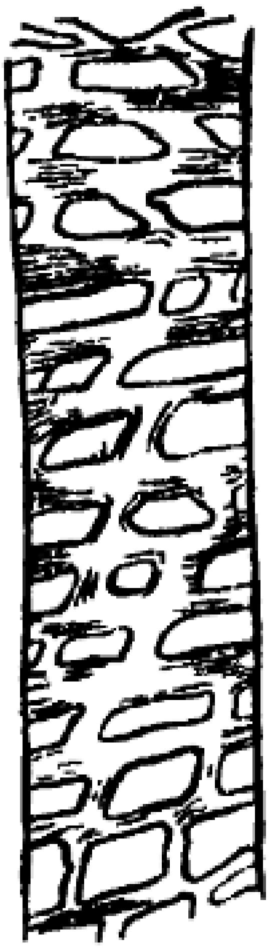
Cell walls are modified from cellulose to serve other purposes which the exigency of situation devolves upon them.

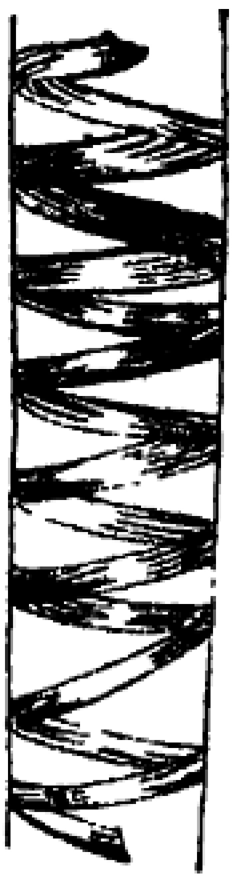
The ordinary modifications are :—

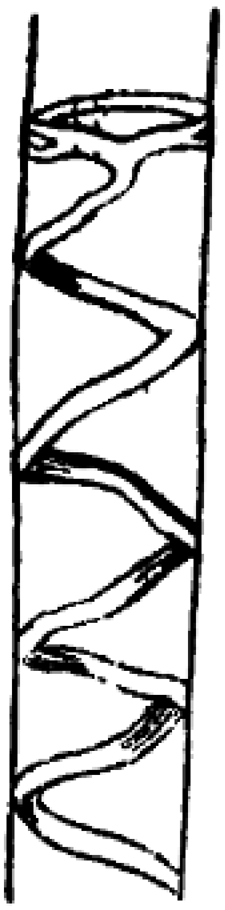
(*a*) **Lignin,** (*b*) **Cutin,** (*c*) **Suberin,** (*d*) **Mucilage,**

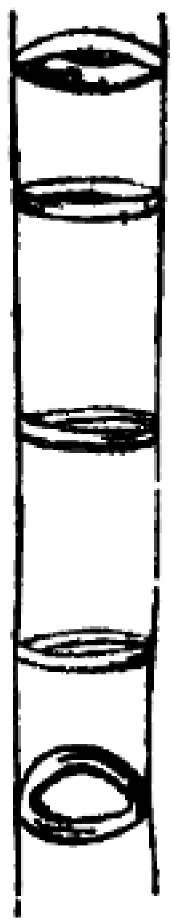
Lignin—the cells whose walls have lignin are called lignified. This is hard and elastic. It is the characteristic of wood cells and other strengthening cells of the plant. It is able to absorb water but cannot retain within it, the absorbed water.


Pitted


Reticular


Spiral


Spiral


Annular

Test—It turns brown to yellow with chlor-zinc-iodine.

Cutin—It is found on the outer surface of the epidermis of plants. The cells having cutin are called cuticularised cells. It is slightly permeable to water. It protects the plant from various external factors.

Test—Turns brown with chlor-zinc-iodine.

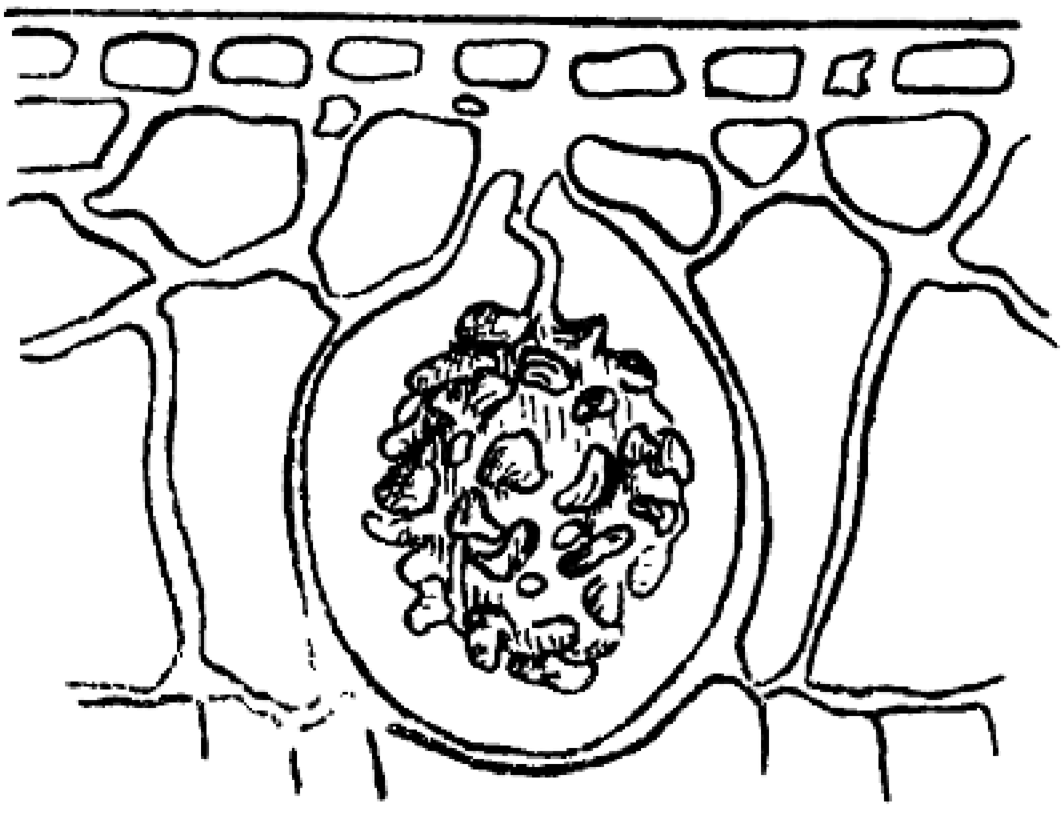
Suberin—it is like cutin but is generally found in the internal structure of plants specially the cork cells. It is not permeable to water.

Mucilage—The cell wall often shows mucilage on it. This is an adaptation to fix the seed to the soil because in seeds of Linseed and Isapgul, the seeds when moistened absorb considerable guantity of water and collect a soapy coating over them.

Test—Turns blue with iodine and sulphuric acid.

Mineral matters—Sometimes mineral deposits of silica and calcium are found on the cells of epidermal tissue which serve to strengthen the tissue and secondly when developed on spiny organs are meant for protection.

Cystolith—These are developed on the walls of certain epidermal cells of the leaves of India-rubber and Banyan trees. These are projections of the cell wall and not a cell content. It looks like a bunch of grapes hanging from a stalk. It is composed of inorganic crystals of calcium carbonate.



Cystolith

Test—Add a drop of acetic acid to the section; the cystoliths become transparent and dissolve; bubbles of gas being given off. When the carbonate is dissolved, a mass of cellulose is left, showing concentric stratification and radial striation.

CHAPTER XX

DIFFERENT KINDS OF CELLS.

Cells assume different forms due to difference in growth. When the cells grow at their ends, they are called prosenchymatous cells *i.e.*, more or less long cells.

If the growth is more or less equal in length and breadth *i.e.*, Isodiametric, it is called parenchymatous cell. A parenchymatous cell may be:—(*a*) Round. (*b*) Oblong. (*c*) Polygonal. (*d*) Star-shaped. (*e*) Brick-shaped (*f*) Cylindrical.

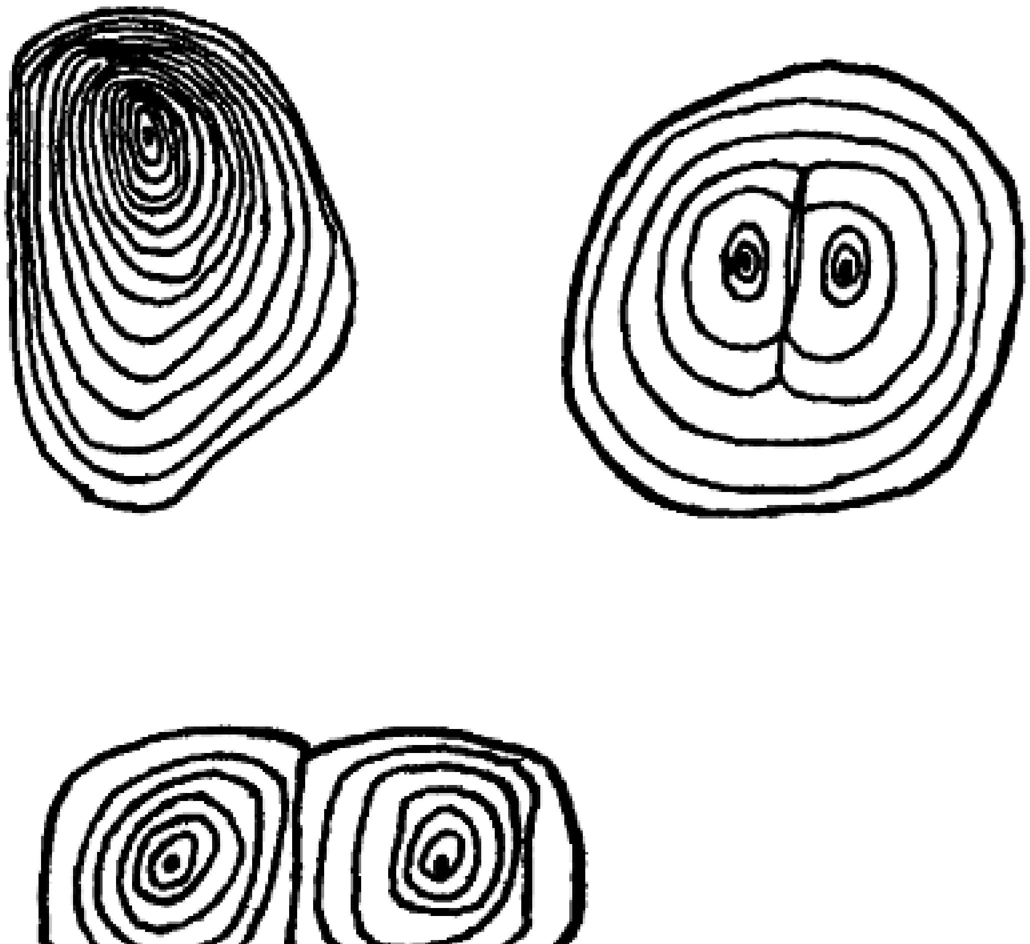
Cell Contents—

The contents of a cell may be living contents or non-living. The protoplasm consisting of cytoplasm, nucleus and plastids are the living contents whereas the non-living contents are the various reserve products or secretory or excretory poducts. The reserve products are meant for the future use of the plants, the secretory products help in some way the life-processes of the plant and the excretory products are the useless products found as the result of metabolic processes.

The reserve products may be starch, sugar, glycogen, cellulose, innulin, proteids, fats and oils.

Starch—is plentifully found in the plant more often in the form of reserve starch. The starch of potato is largely used by human beings. It is a carbohydrate having the formula $C_6H_{10}O_5$. Starch is manufactured by chloroplasts and leucoplasts. Starch grains manufactured by the former are smaller than those by the latter.

Starch grains have a centre called Hilum and straticatons are found around it which represent the mode of deposit of fresh material. When the strtifications are in the form of concentric lines round the hilum, the grain is concentric but when pushed at one end, it is excentric; example of the former is pea, and the latter is potato. When the grains are separate, they are called simple, when two or more are found attached, they are called compound but if a few common lines surround the grains, they are called half-compound.



Starch grains

Starch is insoluble in water and cannot be used by the plant unless converted into the soluble form. There is an active agent which converts starch into sugar and places the food at the disposal of the plant through the intermediation of a starch-splitting enzyme.

Test—Iodine solution turns starch blue.

Sugar—

Sugars are soluble in water and belong to the group of carbohydrates. Forms of cane sugar occur in the stems of sugarcane and in the roots of Beet. Grape sugar occurs in grape and in the fleshy leaves of Onion bulb.

Test—Fehling's solution gives a brick red precipitate with sugar.

Glycogen is starch-like carbohydrate found in Fungi.

Test—Reddish brown with iodine.

Cellulose—is a carbohydrate having the formula $(C_6H_{10}O_5)n$ found plentifully in the seeds of Date, Cocoanut.

Inulin—It is a carbohydrate found in the cell sap as a liquid. Occurs in Sunflower.

Test—with absolute alcohol crystals are formed.

Proteids or Aleurone grains—

These are nitrogenous reserve food materials. The proteid grains are found in the seeds of Pea and Castor oil. In pea, the grains are small whereas in the castor oil seed, they are crystallised and form crystalloids. Crystalloids are proteids and associated with them are globular mineral matters called globoids.

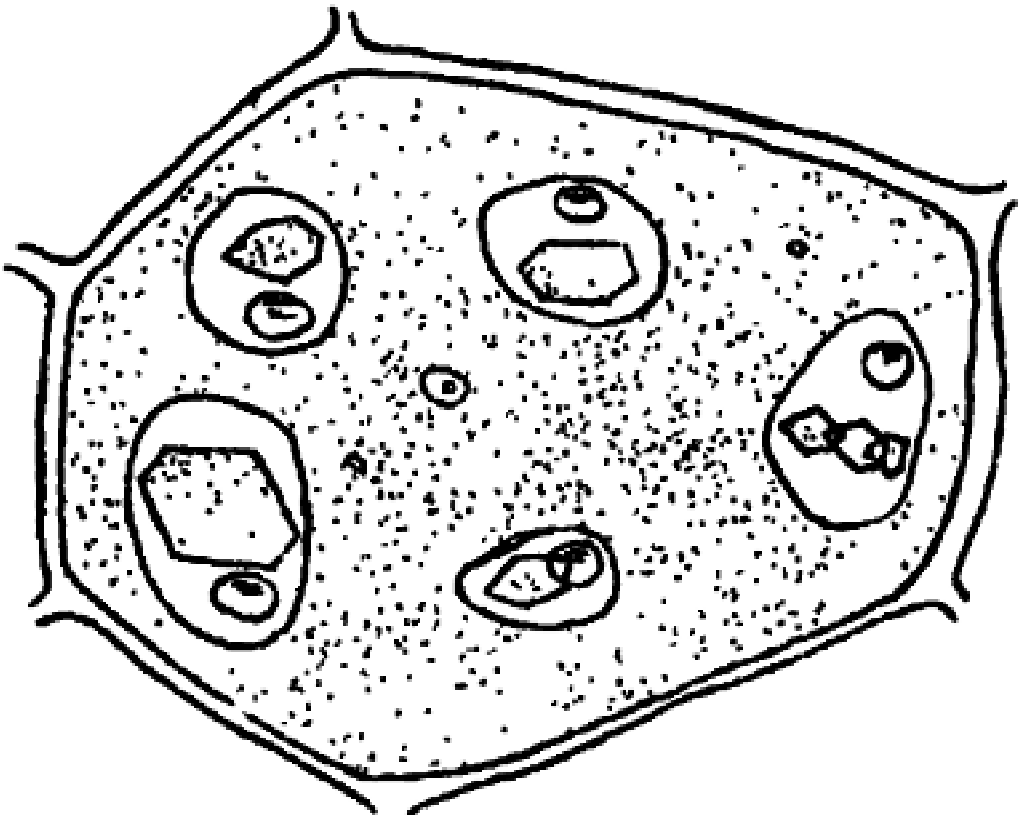
Test—It turns yellow with nitric acid and potash.

Fats and oils—These occur in the form of drops in the seeds of castor-oil, cotton, mustard etc., and in the fruits of olive.

Test—They turn black with 1% Osmic acid.

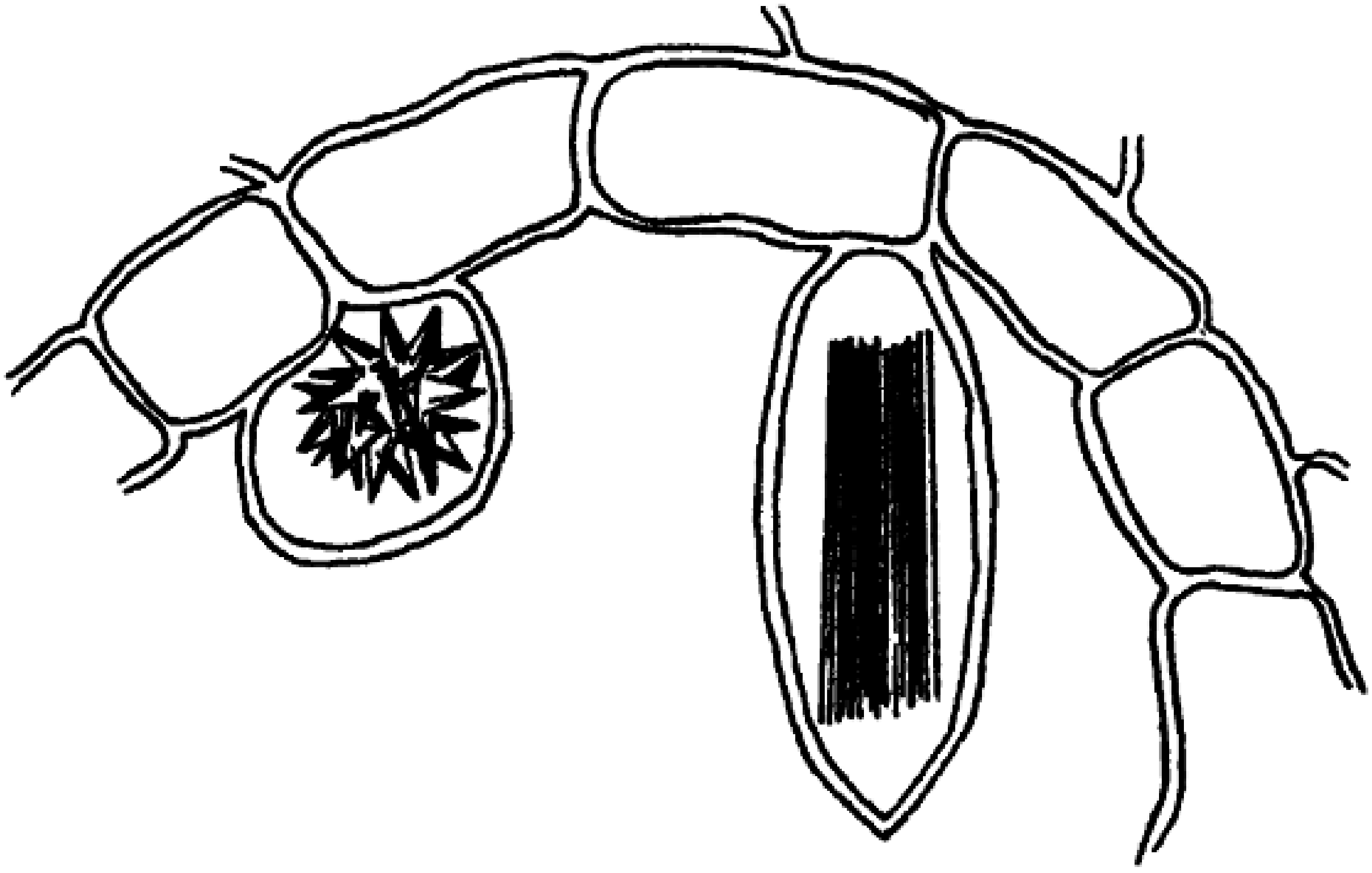
Secretions—

Various secretions are found in the plant-body. The flowers secrete honey and through glands give out odour to attract pollinating agents. The various colours of plants are also secretory products.



Crystalloid and Globoid

Excretions—These are bye-products of metabolism and occur either in isolated ducts or passages mostly towards the periphery so that with the secondary growth when bark is formed they are eliminated. Sometimes they give protection to plants when they give annoyance to intruding grazing animals in the form of bad smell. Excretion differs from secretion in that the former does not help the plant directly. Examples of excretory substances are resin found in resin glands, tannins or tannic acid in tamarind, tea, acacia etc., and alkaloids such as morphine in poppy, thein in tea, cocaine in the leaves of Erythroxylon, caffein in coffee and quinine in the bark of cinchona.



Raphides

Latex is found as a milky substance in the stems of Akanda, in Mansa and Banyan etc.

Sometimes mineral matters are found which are inorganic salts of calcium oxalate in the form of **raphides.** When the raphides are needle-shaped, they are called acicular *e.g.*, Kachu (Colocasia), Ol etc. If star-shaped, they are called sphæ-raphides *e.g.*, stem of beet.

Cell Formation—

Plants and animals are generally multicellular. but the cells are formed as a resut of division. Generally the plant has to begin its life as a unicellular structure just after the union of male and female gametes. The body of the plant or the animal is gradually formed by repeated cell-divisions. Sometimes new cells are formed not by the ordinary method of division but by modification of the structure already present. The commonest method which occurs in the body cells of plants and animals to form new cells is somewhat complicated and is known as **Karyokinesis** or **Mitosis** or **Indirect method** of division. (The term Karyokinesis is now seldom used).

The different methods of cell division are :—

(1) **Direct method** or **Amitosis** or fission or fragmentation. The nucleus elongates after a projection has appeared, and afterwards cytoplasm surrounds each nucleus, a constriction separates the two independent cells *e.g.*, Bacteria, degenerating cells.

(2) **Karyokinesis,** it takes place in the body cells of plants and is divided into four stages. The resting nucleus gradually forms a number of chromosomes. The nucleolus and the nuclear membrane disappear.

In the second stage which is called **Metaphase,** the nuclear spindle is fully formed and the chromosomes which are V or U-shaped arrange themselves in the equator with their apices directed opposite to one another. The chromosomes, in the metaphase longitudinally split. In the third stage, the chromosomes turn their apices towards the poles and travel on the threads of the spindle. This travelling phase of the chromosomes is **Anapase.** The last phase is called the **Telophase.** Here the chromosomes aggregate at the poles and reconstruction of the nucleus begins, so that from the original cell, two new cells are formed.

In *karyokinesis*, there is longitudinal splitting of the chromosomes, so that each daughter nucleus receives the same amount of nuclear material. The chromosomes are very important structures as they are regarded as the bearers of hereditory characters.

In summary, the fundamental feature of nuclear division (indirect) is an equal division of the chromatin of the nucleus, half of which is passed to each of the two daughter nuclei. Briefly what happens in mitosis is, first the aggregation of the chromatin into recognisable chromosomes, the rod-shaped bodies characteristic of the dividing nucleus. Next, the nuclear membrane disappears and a spindle shaped structure which in most stained preparations seems to be composed of fibrils, appears in the cell. Following the formation of the spindle, the chromosomes arrange themselves at the equator of the spindle, splitting lengthwise just before they assume this position. The fibres of the spindle appear to be attached to the chromosomes. This arrangement of spindle fibres and chromosomes suggests that the two halves of each chromosome are pulled apart (according to others, the halves of chromosomes separate owing to repulsive forces). Finally, these separated halves pass to the opposite poles of the spindle and form the chromatin mass of the new daughter nuclei. A cell-wall forms at the equqator of the spindle, thereby separating the two new nuclei, each of which receives approximately one-half of the cytoplasm.

The condition of the nucleus when not dividing is called the **resting stage** or **interphase** *i.e.*, the phase between divisions. In the order of their sequence the phases are the **prophase,** the **metaphase,** the **anaphase** and the **telophase.** The **prophase** is the first phase of the division stage of the nucleus. It extends from the first change in the resting stage during which the chromosomes become recognizable entities to the beginning of the **metaphase,** or changing phase, during which the split chromosomes collect at the equator of the spindle. The **anaphase** or going back phase, is characterised by the passage of the separated halves of the chromosomes to the position of the two new nuclei. In the **telophase** or last phase the chromosomes are consolidated into the new nuclei. The activity of the dividing stage gradually subsides during the telophase and finally appears to cease altogether. At this period of the telophase, the last phase of the dividing stage ends and the nucleus is said to have resumed its resting stage or, as some authors designate it, the interphase.

(3) *Reduction division* or **Meiosis.**

This type of division is confined to reproductive organs of plants and animals. This means that the original number of chromosomes is reduced to half. As a result of union of male and female cells, two nuclei fuse together, if the number of chromosomes is not reduced, then every union means the doubling of chromosomes and ultimately the number would have been infinite so reduction is absolutely necessary before union of cells takes place.

(4) Free cell formation.

In free cell formation, the nucleus divides by Karyokinesis into two, but the partition separating the cells does not appear, instead the daughter nuclei again divide so that a large number of nuclei are formed in one cell. These nuclei collect some cytoplasm with each so that a number of naked cells are formed.

Ex.—formation of endosperm of seeds.

(5) Budding.

In budding an outgrowth appears which in its turn bears another so that a chain is formed.

Ex.—Yeast.

Formation of new cell without division of a pre-existing cell.

(6) Conjugation.

Two similar gametes unite together to form the zygospore. Nucleus fuses with nucleus and cytoplasm with cytoplasm. The zygospore secretes a wall round itself.

Ex.—Conjugation is found in Mucor, Spirogyra etc.

(7) **Fertilisation,** means the union of male and female gametes *i.e.,* the gametes are dissimilar. As a result of fertilisation, an oospore is formed. The common name both for *oospore* and *zygospore is zygote.* The oospore secretes a wall round it. Fertilisation occurs in the Moss, Fern etc.

(8) **Parthenogenesis,** when the female gamete without fertilisation behaves like a zygospore. The process is called parthenogenesis.

Ex.—Spirogyra.

CHAPTER XXI

TISSUES.

A tissue is a collection of similar cells adapted for a particular function. There are various tissues in the plant, performing different functions. Tissues are mainly divided into two groups :—

(*a*) **Meristematic tissues** and (*b*) **Permanent tissues.**

a. Meristematic tissues—

Meristematic tissue is composed of cells capable of further growth and division which are generally found at the growing point of root or stem. The growth of the meristem of the apical portion of the root or stem results in the increase in length of the structure. After some growth has taken place, the meristematic tissue assumes the permanent condition. The kinds of meristematic tissues are :—

(1) **Primordial meristem**—the apical cell found at the apex of the root or stem often gives rise to the meristematic tissue. This is the originator of the meristematic tissue. In phanerogams, a group of initial cells develop into the meristem.

(2) **Primary meristem**—the primordial meristem develops into the primary meristem consisting of **dermatogen**, **periblem** and **plerome** beginning from the outside. In the case of the growing point of the stem, the dermatogen develops into the epidermis, the periblem

into the cortex and the plerome into the central cylinder. Some of the cells of plerome are long and specialised and give rise to procambium strands which develop into the vascular bundles. In the case of the root, there is an additional layer called the region of root-cap or calyptrogen in addition to the three layers.

(3) **Secondary meristem**—sometimes the permanent tissues specially of the cortical part in stem become meristematic and in the root in the region of the pericycle; there is also the formation of the secondary meristem in the stelar region as a result of which wood and bast cells are cut off. This development of meristematic tissue in the permanent region is called secondary meristem.

b. Permanent tissues—

Permanent tissue has assumed a form which does not change and is incapable of further growth. The permanent tissues may be divided into:—

(1) **Cellular,** (2) **Vascular,** (3) **Laticiferous** and (4) **Glandular.**

Cellular—

The cellular tissue may be composed of parenchyma or prosenchyma. Parenchymatous cells are more or less isodiametric. These cells are composed of cellulose cell-walls and are thin-walled. They may be:—

(*a*) **Chlorenchyma,** or tissue having chlorophyll in their cells. These cells occur in the leaves. They are known as photo-synthetic cells capable of manufacturing organic food.

(*b*) **Aerenchyma,** this tissue occurs in water-plants, having large intercellular spaces. The air which is contained in the large spaces give buoyancy to the plant. It occurs in root, stem or leaves of water-plants.

(*c*) **Collenchyma,** these are parenchymatous cells but are thick-walled at the corners of cells, generally occuring in the cortex. These are found in herbaceous plants and give strength to them. Chloroplastids might occur in them.

(*d*) **Wood parenchyma,** occurs in the secondary wood of Dicots. They are lignified tissue and are thick-walled. Prosenchyma consists of long cells and are generally associated with the conduction of water.

Sclerenchyma are dead cells and consists of either parenchyma or prosenchyma. The walls are lignified. Hard bast and wood fibres are composed of sclerenchyma. They give strength to the plant.

(2) Vascular—

These consist of vessels *i.e.,* cells which have lost their partition-walls and have fused with one another. Fundamentally, there are two kinds of vascular tissue, one is **xylem** or **tracheal** tissue or **hadrome** and the other is the **Sieve tissue or Phloem or Leptome.** The xylem carries the water and dissolved food-matters from the soil to the leaf, the phloem translocates or transfers the prepared organic food from the leaf to different parts of the plant. Xylem consists of *tracheæ* or *tracheides* with parenchyma and sclerenchyma.

The *trachea* is a true vessel which is formed by the disorganisation of the partition-walls of several cells. Tracheid is a single elongated cell. The wall of *tracheæ* or *tracheides* may be pitted, annular, scalariform, reticulate etc.

Xylem has twofold function; (1) *Conduction* of water and (2) *Mechanical* support.

Phloem consists of sieve tubes and companion cells. The cells are thin-walled and are provided with sieves so that they are called sieve-tubes. The sieves are perforations which form callus in winter but dissolves in spring. They are rich in proteids, carbohydrates and other organic food. The sieve-tubes are the channels through which food is sent to different parts of the plant.

(3) Laticiferous tissue—

✓ These cells give out a milky juice or watery juice called latex. The juice is regarded by some to be an excretory product while others regard it to be secretory product. Laticiferous tissue may be in the form of single cells called laticiferous cells as in the case of Akanda, Euphorbia. This is a much branched cell in the form of a coenocyte. Laticiferous vessel is formed by the absorption of the partition-walls of some cells and form a much branched structure.

Ex.—Plantain, Sunflower, Shealkanta (Argemone).

(4) Glandular tissue—

Glands may be distributed in various parts of the plant which secrete substances for different purposes. Glands may be multicellular solid glands, *e.g.*, nectaries of some flowers. Hollow glands are found in the oil glands of orange, lemon etc.

CHAPTER XXII

TISSUE SYSTEM.

A **tissue** means an aggregation of cells for a definite work but a system is a collection of tissues for the proper performance of certain functions. There are three main tissue systems :—

(1) The *tegumentary* or *Epidermal* tissue—system.

(2) The *conducting* or *Vascular* system.

(3) The *fundamental* or *ground* tissue system.

It is the primary meristem that gradually forms the different tissue—systems. Thus,

Dermatogen	Epidermis			Epidermal System
Periblem	Ground tissue of cortex	Hypodermis General cortex Endodermis		System of Ground tissue.
Plerome	Pith			
	Stelar system	Conjunctive tissue	Pericycle Medullary rays	
		Vascular Bundles		Vascular system.

The tegumentary system corresponds to the outer skin of animals. Usually the outer tissues of the plant form the tegumentary system consisting of epidermis and its associated structures. The epidermis is usually one layered but occasionally it is many layered as in the case of Velamen on the roots of epiphytic orchids and the leaves of Banyan, India-rubber show many layered epidermis.

Stomata—

The epidermis is not entire but has some openings called stomata. Each stoma is an opening guarded by two cells called guard cells having chloroplasts. When there is plenty of water, the guard cells curve and there is full opening of stoma but as a result of loss of water, the guard cells become flaccid and the pore closes. The opening and closing of the stomata are of great significance to the plant.

Formation of stoma—

The nucleus of one of the epidermal cells divides into two and a partition-wall is formed, thus forming two new cells. There is now a longitudinal splitting along the common wall, leaving a space, this aperture is the stoma and the two cells form the guard cells.

Function of stomata—

Stomata serve three functions of the plant.

(*a*) Respiration, CO_2 passes from the plant through stomata to the atmosphere.

(*b*) Transpiration, water-vapour escapes from the plant through stomata.

(*c*) CO_2 enters through stomata into the plant during photosynthesis. Therefore the chief organ for gaseous interchange of the plant is the stoma.

Stomata are found on the undersurface of leaves of land plants and on the upper surface of leaves of water-plants and on herbaceous stems. In plants where there is formation of bark, another structure is developed from stoma called lenticel.

The stoma is protected by the development of hairs or the epidermis develops sunken stomata as in the desert plants to prevent excessive loss of water. There is another type of peculiar stomata called hydathodes which secrete water from leaves and are found in Colocasia (Kachu), Lotus and Grass.

The hairs found on the epidermis of roots serve a very important function as they absorb water from the soil.

The epidermal system mainly protects the inner parts from external injury.

The conducting or Vascular system—

As the name signifies, it is responsible for the conduction of raw food material and transfer of prepared food from the leaves to different parts of the plant. This system essentially consists of xylem, cambium and phloem. Xylem conducts raw food and phloem transfers organic food of plants.

Xylem is also called Hadrome or Wood. Xylem consists of tracheal tissue with wood parenchyma and wood-fibres. The *xylem* of fern has only tracheids. Xylem consists of protoxylem and metaxylem. Protoxylem are smaller vessels and formed first and consists of spiral and annular vessels and are found towards the centre in stem and the larger vessels are known as metaxylem groups formed after protoxylem and consists of reticulate and pitted vessels. The cambium is a strip of meristematic tissue lying between xylem and phloem. Phloem is also known as leptome or Soft Bast. Phloem is generally associated, with companion cells in dicots.

The wall of phloem vessels are thin and made of cellulose. They transfer organic food of plants.

Vascular bundles—

There are several types of vascular bundles :—

(1) **Collateral,** when the xylem and phloem groups are arranged side by side. The phloem being external *e.g.*, Rose, Pea.

(2) **Bicollateral,** if there be two sets of Phloem vessels on the inner and outer sides of a bundle, it is called bicollateral *e.g.*, Gourd, Cucurbita in general.

(3) **Concentric,** if the xylem is surrounded by the phloem or the phloem by xylem, the bundle is called concentric. The former is hadro-centric *e.g.*, Fern and the latter is lepto-centric *e.g.*, Dracena.

(4) **Radial,** this is found in roots of Dicots and Monocots where the xylem and phloem groups are arranged separately in the form of radii of a circle. The protoxylem in roots is towards the circumferance.

If there be cambium in a collateral bundle, it is called open ; but if the cambium is absent in the bundle, it is called closed.

Ground tissue system consists of cortical tissue and conjunctive tissue. Cortical tissue consists of hypoderma, cortex and endodermis.

Hypoderma may be formed of collenchyma or sclerenchyma or of ordinary parenchyma. Collenchyma with chloroplasts can prepare food. Sclerenchymatous hypoderma is a strengthening tissue. Sclerenchymatous hypoderma is peculiar to Monocotyledons.

Cortex proper is parenchymatous and stores up food or conducts carbohydrates and assimilates food.

Endodermis—

It is the limit of the cortex on the inner side. It is also known as Starch-sheath because it stores up starch. The radial walls of endodermis are thick in roots. When the endodermis is old, all the cells of the layer become corky leaving a few thin-walled cells called Transfusion cells. The endodermis is also called the Casparian band.

Conjunctive tissue consists of pith, pericycle and medullary rays.

Pith occupies the centre of the stem and sometimes it may be hollow.

Pith consists of parenchymatous cells and performs the functions of :—

(*a*) Conduction of water, and (*b*) storage of water and food-material.

Medullary rays store up reserve food but mainly carry food in solution from the vascular bundle to the cortical region. They are composed of parenchymatous cells running from the pith to the pericycle between vascular bundles.

Pericycle—It occurs in single or many layers just outside the phloem. It may be composed of parenchymatous cells and perform the function of storage of food. Sometimes, it is many layered and formed of sclerenchyma when it is a mechanical support.

Stele—

The central portion of root or stem formed by pericycle, vascular bundles and pith go by the name of Stele.

CHAPTER XXIII

ANATOMY OF PLANTS.

Transverse and longitudinal sections of **Dicot stem.**

A transverse section of Dicot stem shows the following structure from the outside :—

(*a*) *Epidermis* consisting of a single layer of cells with multicellular hairs. The outer walls of the cells are cutinised.

(*b*) *Cortex* consisting of several layers of parenchymatous cells with intercellular spaces. (Sometimes collenchyma is found here).

(*c*) *Endodermis* is made of one layer of cells.

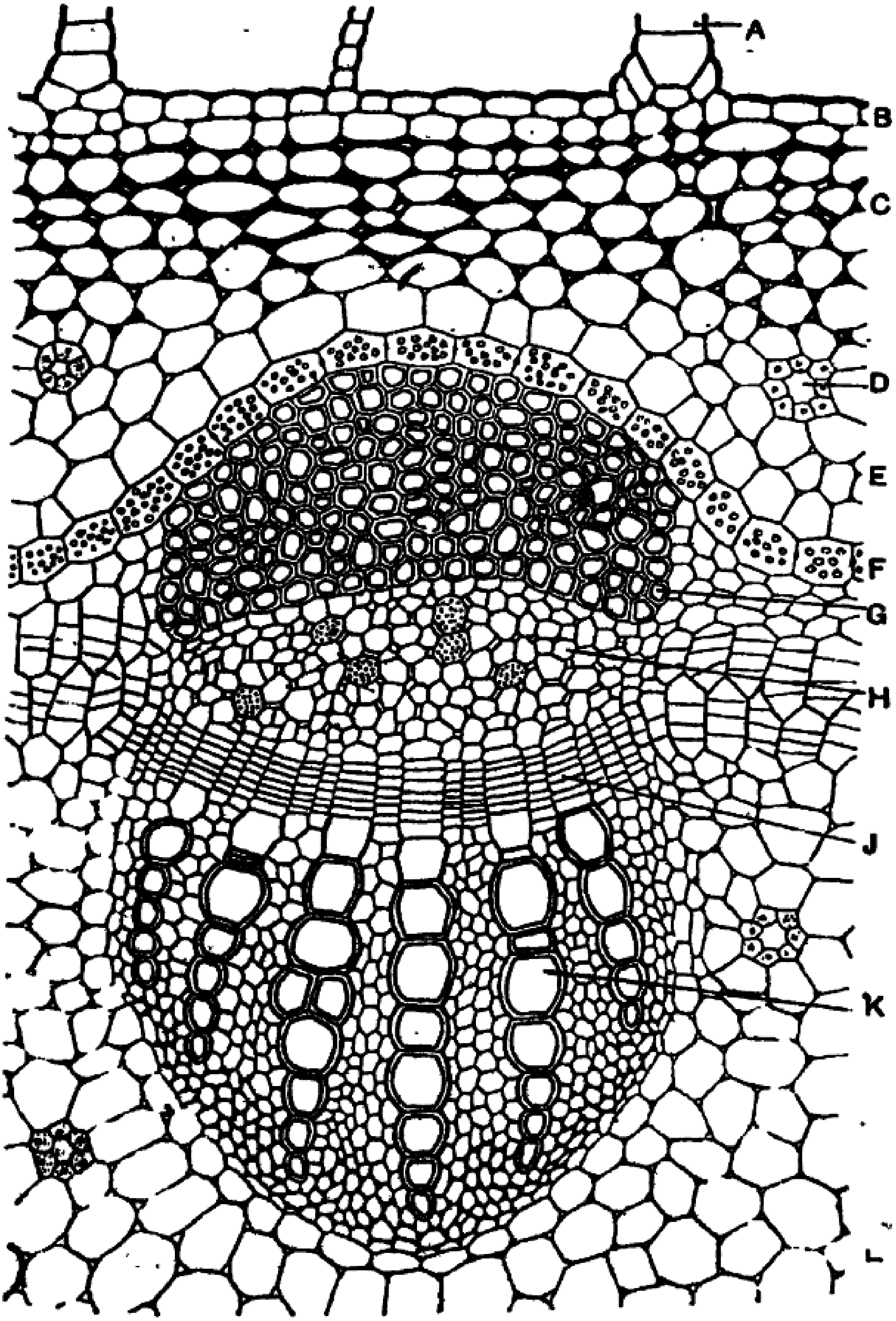
(*d*) *Pericycle* consisting of a few layers of cells (usually one layered).

(*e*) *Vascular bundles* are arranged in the form of *a* ring. Each vascular bundle consists of xylen and phloem with cambium in the middle.

The xylem is made of metaxylem and protoxylem groups. The protoxylem is towards the centre or pith. The phloem is composed of metaphloem and protophloem. The protophloem is towards the outside. Between two vascular bundles, the medullary rays are situated running from the pericycle to the pith.

(*f*) *Pith* consists of parenchymatous cells with intercellular spaces and occurs in the centre.

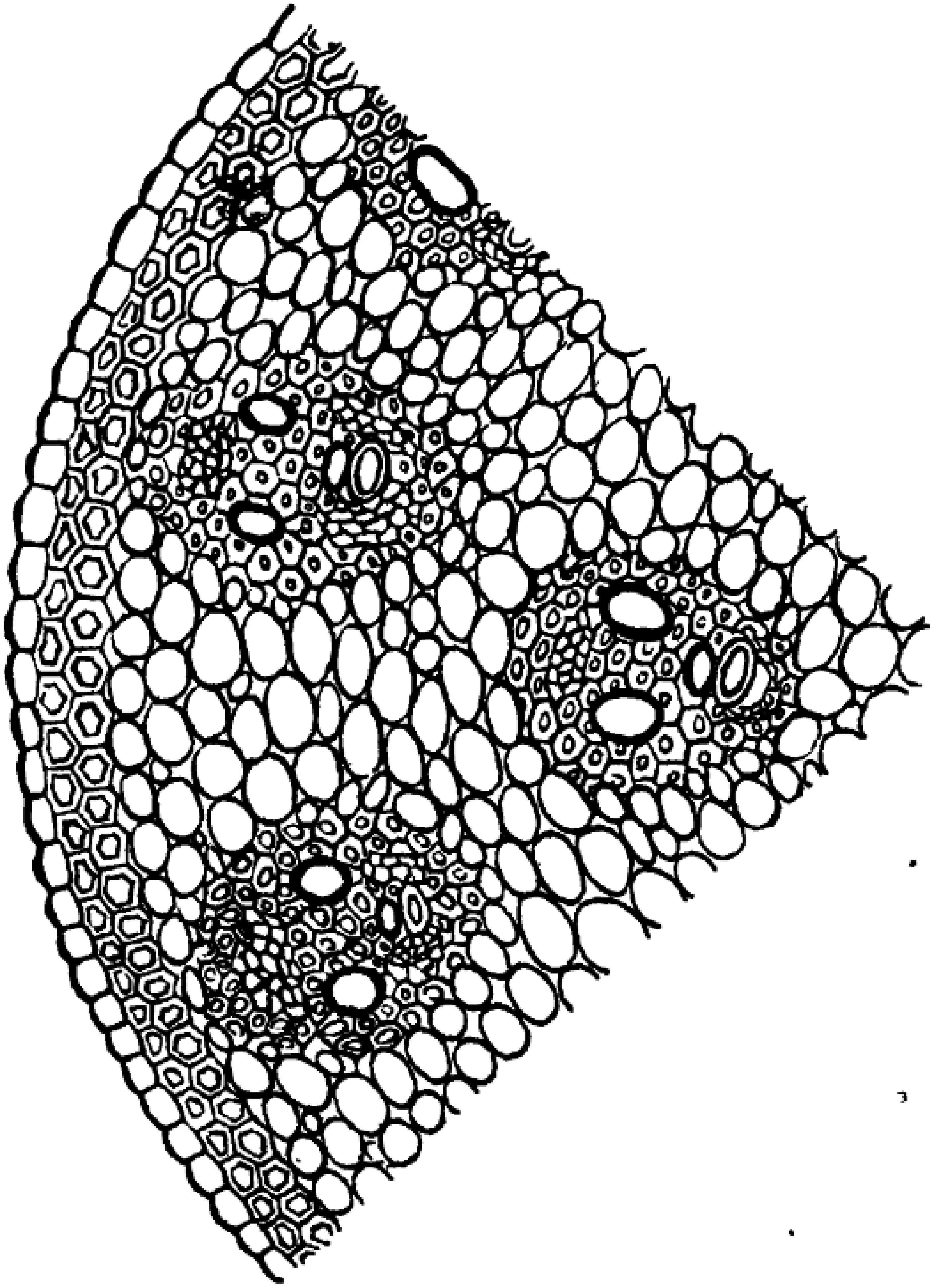
In the longitudinal section of stem, all the structures are found and the annular, spiral vessels of xylem and



A=hair, B=Epidermis, C=collenchyma,
D=resin duct, E=Cortex, F=Endodermis,
G=Hard bast (pericycle), H=Phloem, J=Cambium,
K=Xylem, L=Pith.

the companion cells of phloem become distinct and prominent.

Transverse section of **Monocot stem.** The parts are :—



T. S. of Monocot Stem.

1. *Epidermis* is one layer thick with cutinised outer walls.

2. *Hypodermal Sclerenchyma* consisting of a few layers of sclerenchymatous cells.

3. *Ground tissue* consisting of parenchymatous cells with intercellular spaces.

4. *Vascular bundles* are scattered throughout the ground tissue.

5. *Each vascular bundle* consists of *xylem and phloem.* The xylem vessels are in the form of " V " and the phloem is towards the open limb of " V." The bundle is surrounded by sclerenchyma sheath. There is no distinct pith or medullary rays. There is no cambium so the bundles are closed. Ordinarily, cambium is absent in Monocots but in certain Monocots *e.g.*, Dracena, Yucca there are cambium, so secondary growth is possible in them.

Transverse section of **Dicot root.**

1. *Epidermis* or Epiblema or piliferous layer. There is one layer of cells with non-cutinised walls with a number of unicellular hairs called root-hairs.

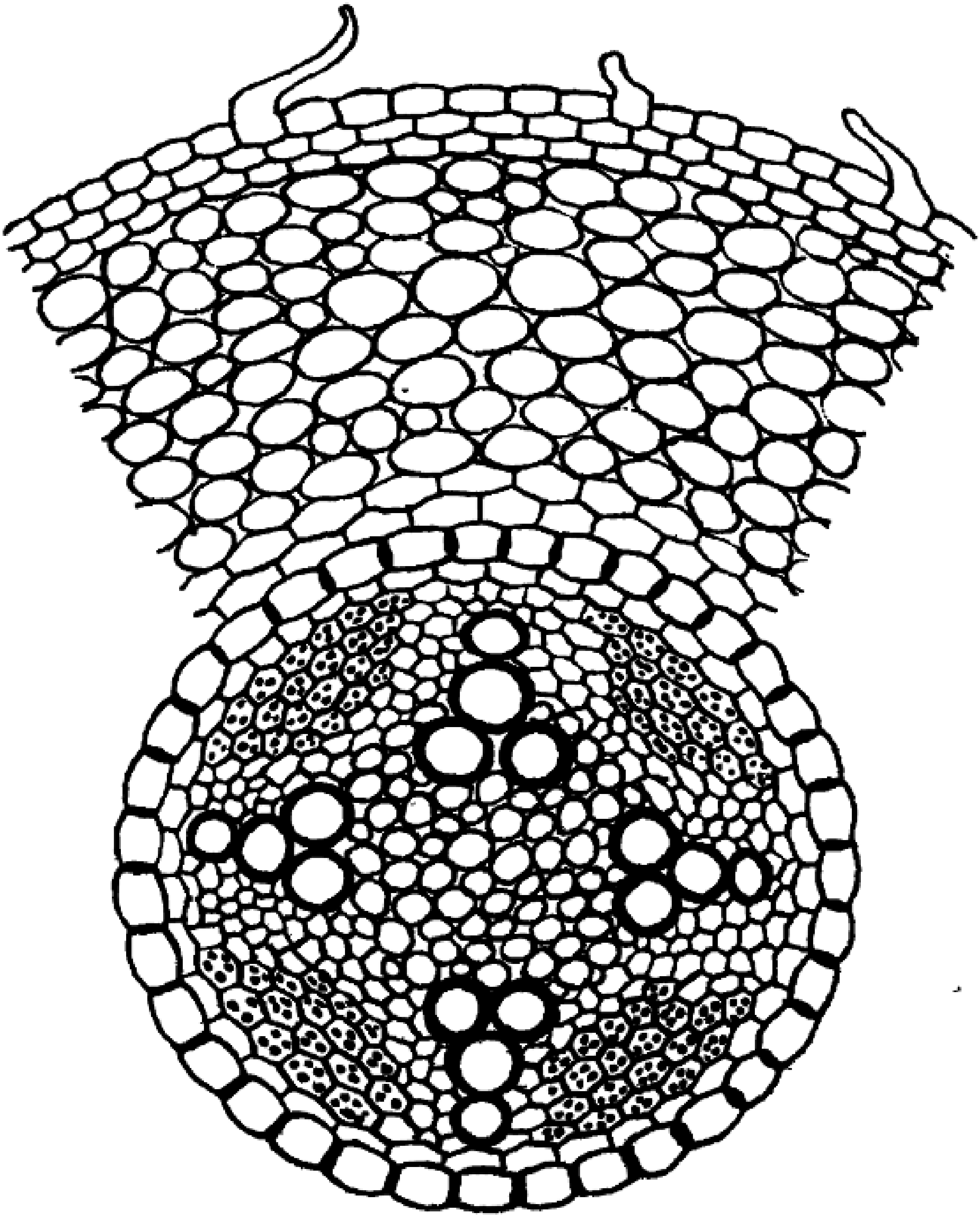
2. *Cortex* has many layers of parenchymatous cells with intercellular spaces, often it is divided into exodermis, cortex proper and endodermis. The exodermis is the layer just below the epidermis. The cortex consists of thin parenchymatous cells.

3. *Endodermis* consists of one layer of cells with thick radial walls.

4. *Vascular bundles* are in separate groups of xylem and phloem bundles arranged alternately. The bundles are radially arranged. The protoxylem is towards the circumferance. The number of bundles is either 2, 4 or 6.

6. There is a distinct *pith.*

T. S. of Dicot root.



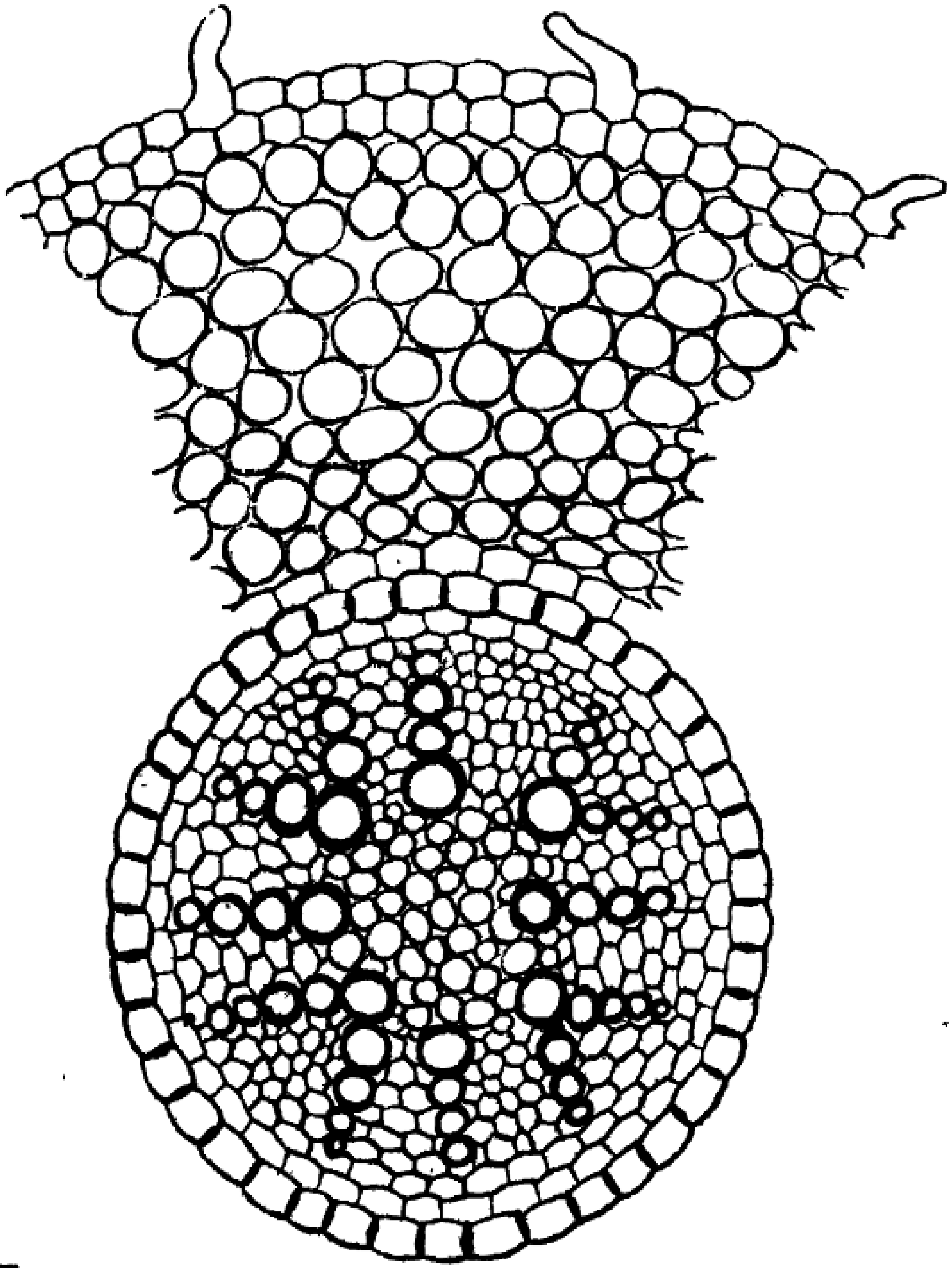
Transverse section of **Monocot root.**

1. *Epidermis* or *Epiblema* from the outside.
2. *Cortex.*
3. *Endodermis.*
4. *Pericycle.*

5. The *number* of bundles *is numerous* and the arrangement is radial *i.e.*, Xylem and phloem groups are arranged alternately in different radii.

6. There is a *large pith.*

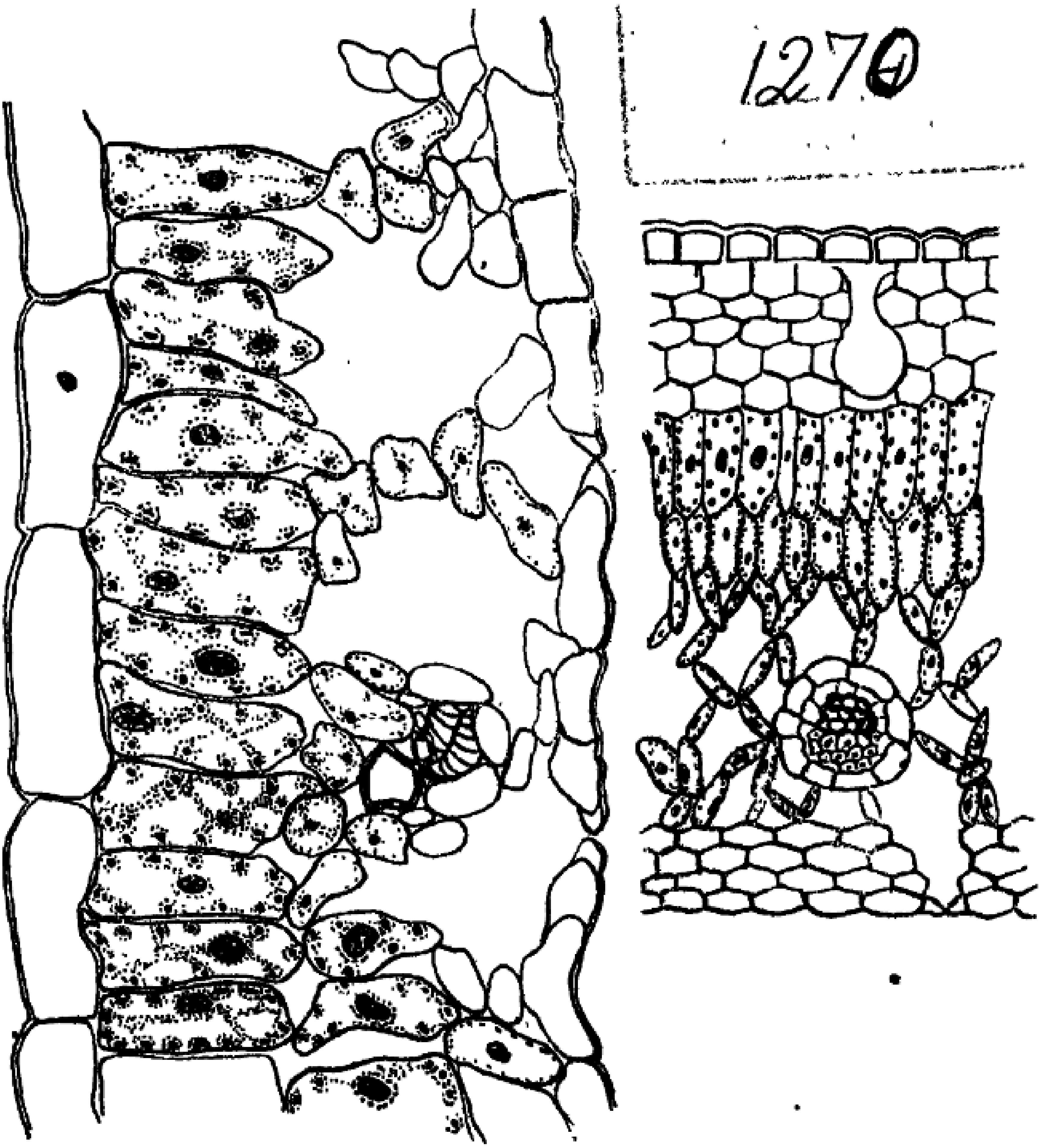
T. S. of Monocot root.



Transverse section of **Dorsiventral leaf.**

This type of leaf shows in section upper and lower epidermis and in India-rubber leaf, the epidermis is three-layered. There are cystoliths in the epidermis. The lower epidermis shows some stomata. The epidermis has cuticle on the outer surface. Between the upper and

1270



T. S. of Dorsiventral leaves

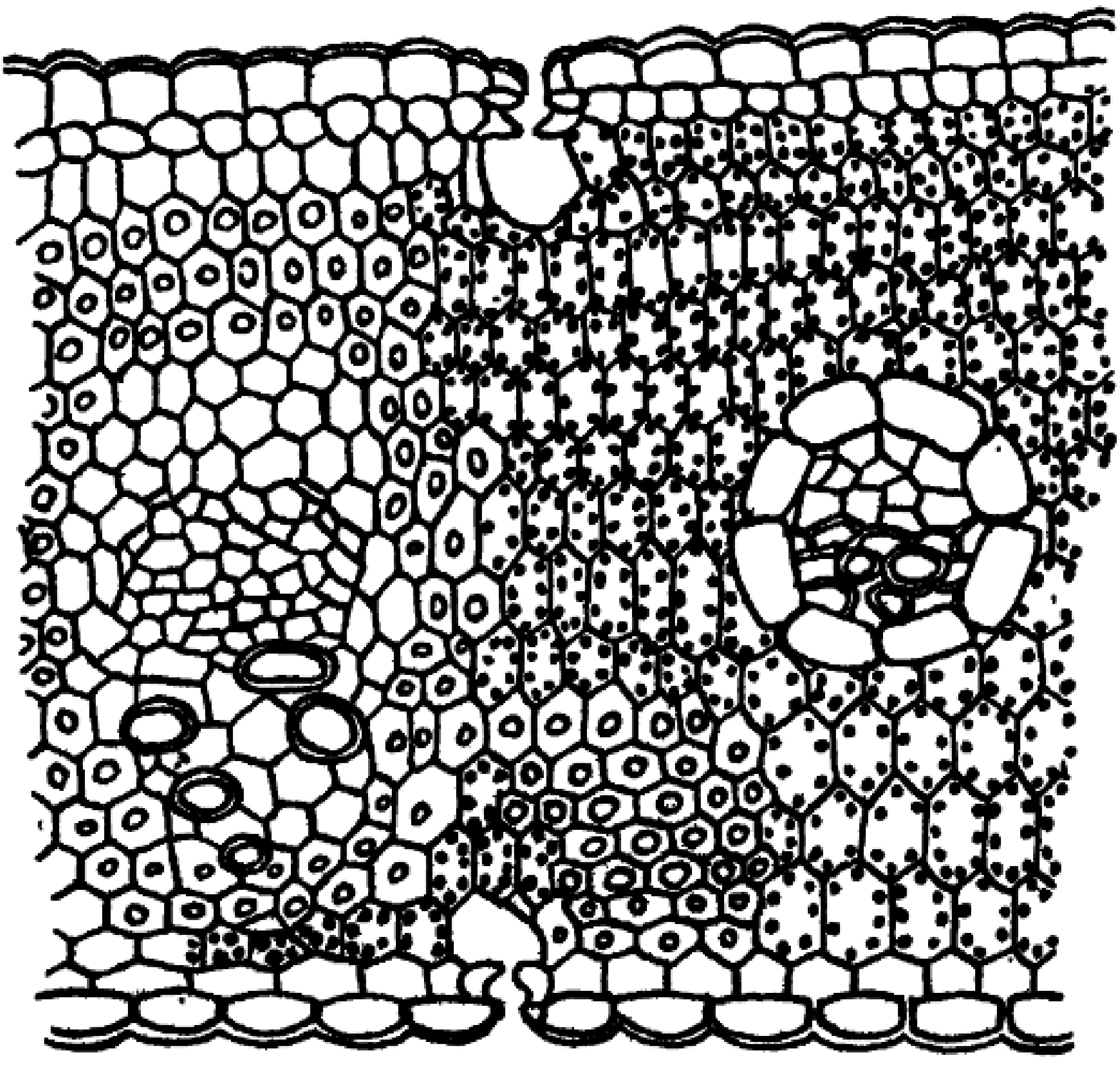
lower epidermis is the *mesophyll.* Mesophyll consists of *palisade* and *spongy parenchyma.* Palisade parenchyma has long cells with numerous chloroplastids in them.

The palisade parenchyma has no intercellular space. The spongy parenchyma on the other hand has plenty of intercellular spaces and are more or less oval or round in form. If the section passes through a midrib, it shows the same type of stele as the stem. Generally, the xylem is towards the upper epidermis and phloem towards the lower in the case of smaller veins.

Transverse section of **Isobilateral leaf.**

In the case of Datepalm, there is *Isobilateral* type of structure *i.e.* there is upper epidermis and lower epidermis but stomata are present in both. Below the epidermis, there is found a layer of colourless cells. There is no *distinction of palisade and spongy parenchyma.*

T. S. of Isobilateral leaf.



There are large and small veins. The small have xylem and phloem surrounded by a Sheath of parenchyma whereas the larger veins are covered by sheaths of Sclerenchyma.

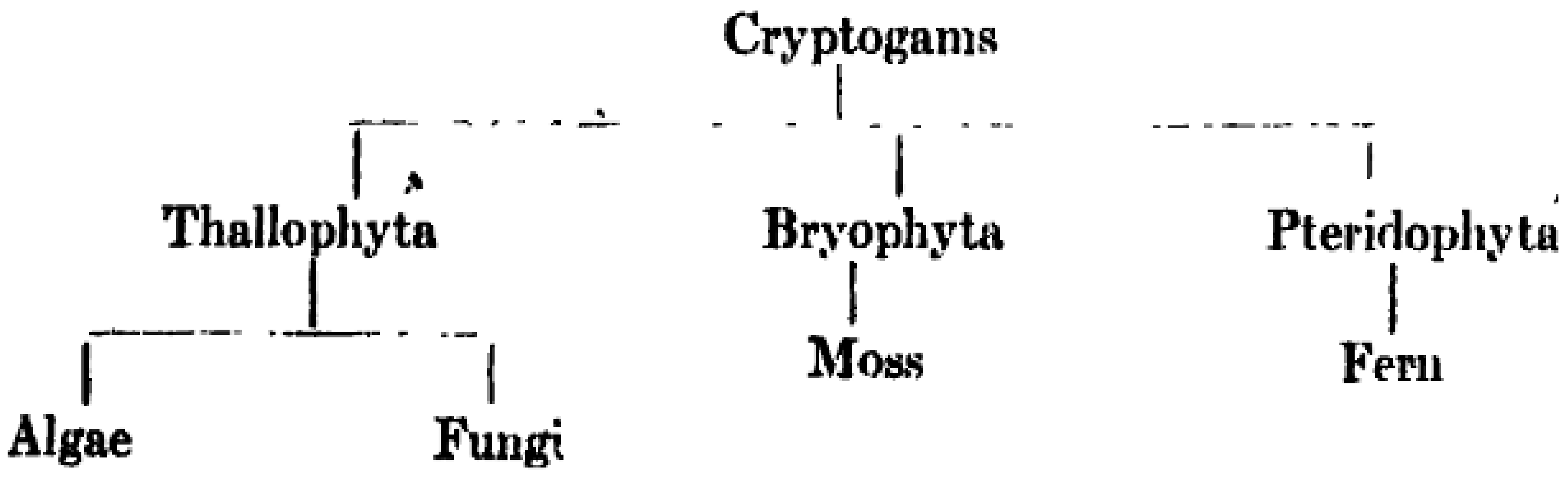
Secondary growth and formation of Bark.

The stems and roots of Dicots generally have secondary growth. The intrastelar secondary growth results from the activity of interfascicular and fascicular cambium in stem and extrastelar secondary growth of stem is due to the attainment of meristematic condition by some cells of cortex. As a result, cork is produced and all dead tissue outside the cork-cambium form the bark of plants.

CHAPTER XXIV

CRYPTOGAMS AND SPERMATOPHYTA.

The **cryptogams** are not the plants with which we are familiar *i.e.* they are neither like the pea, rose, mango nor like the maize, grass, palms etc. They are peculiar in that they do not produce the seeds but produce unicellular reproductive structures called **spores.** Some are very minute and can not be seen with the naked eye and require the use of the microscope. All disease producing bacteria as also beneficial bacteria like the lactic acid bacillus of sour milk belong to the group of cryptogams. Various examples of cryptogams are found around us namely the toadstool popularly called " Bangerchata " or the white incrustation found on damp articles in the rainy season or thread-like structures found floating in the tanks or the multi-coloured ribbons found floating near the sea-shores of Puri or South India. The cryptogams are divided into three main groups.



The first group is Thallophyta because the plant-body is an undifferentiated mass called Thallus. In thalloid structure, there is neither root nor stem nor leaf. They may be composed of one cell or many cells. The thallophyta again is divided further into **Algae** and **Fungi,** on account of some fundamental difference.

Algae are generally capable of manufacturing their own food and they contain some colouring matter either green, red, yellow or brown. But **Fungi** are devoid of the colouring matter, in other words they cannot prepare their food but have to depend upon food prepared by other plant or animal.

Fungi live either as **parasite** or as **saprophyte.** When they live on living matter, they are called parasites but when they live on dead organic matter, they are known as saprophytes. Examples of Algae are Spirogyra, Diatoms etc. and examples of Fungi are Bacteria, mucor, yeast etc.

The second group is the **Bryophyta.** Here the differentiation of stem and leaf is found but no true roots. The plant-body is a step above the thallophyta, although in some bryophytes namely Marchantia, the plant-body is still a thallus. The plant-body although showing difference of stem and leaf represents the gametophyte—phase. Here the sporophyte is not independent and lives as a parasite or as semiparasite upon the gametophyte. There is no separate existence of gametophyte and sporophyte, one is dependent upon the other. Example—Moss.

The third group is the **Pteridophyta.** The group is very important from the point of view of evolution. Here there is differentiation of root, stem and leaf and they seem to approach the Phanerogams, the group highest in development in the plant kingdom. The commonest example is the Fern. The plant itself is the sporophyte and the gametophyte is less prominent but independent. There is a reversion of the dominance of the gametophyte that is found in the Bryophytes. In the higher plants like rose and pea, the plant-body is the sporophyte and the gametophyte really becomes inconspicuous.

Spermatophyta—

Spermatophyta are characterised by :—

(1) The **formation of a pollen-tube;** (2) the **production of seeds.**

The cryptogams are spore-producing plants. Spermatophyta are sub-divided as follows :—

Spermatophyta

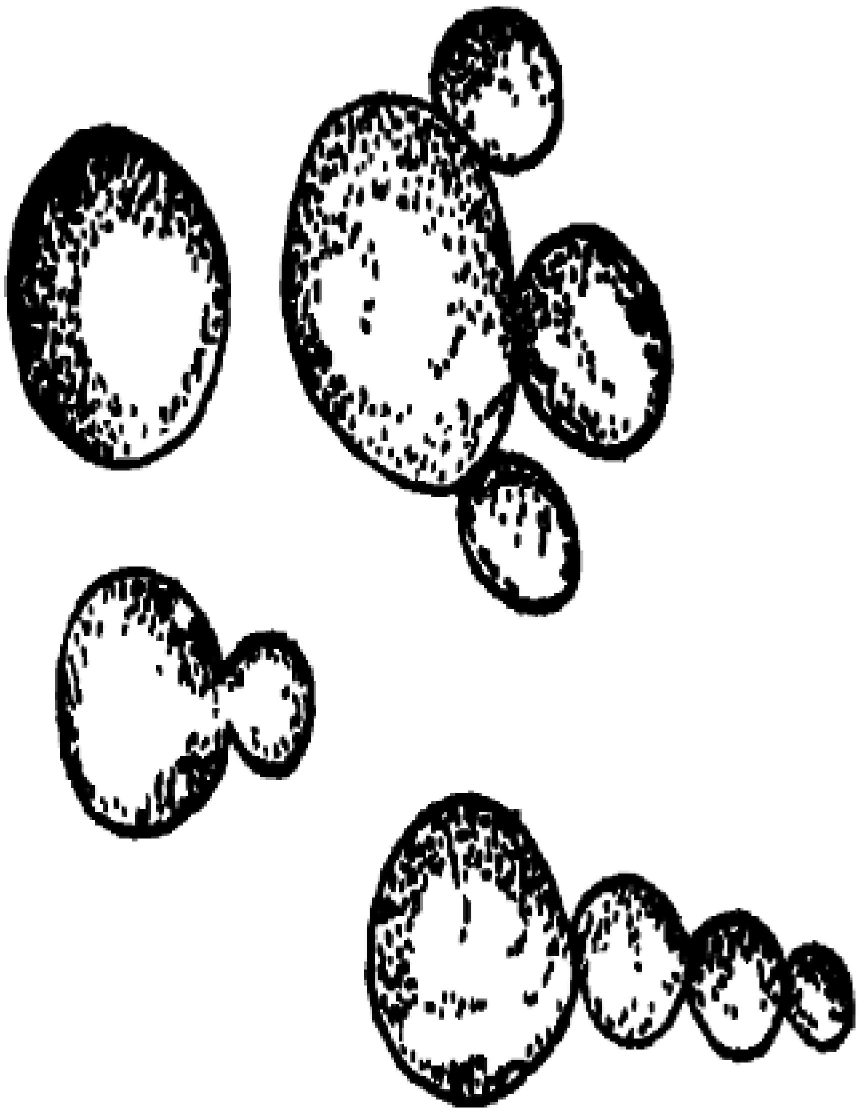
Angiosperms
Gymnosperms
e.g. Pine.

Dicotyledons
e.g. Pea.

Monocotyledons
e.g. Maize.

The first group is the **angiosperms,** they are close-seeded plants *i.e.,* their seeds are found in a case called ovary whereas the **gymnosperms** are called open-seeded plants *i.e.,* their seeds are not found in a case but are open. The ordinary plants like pea, rose etc. are all angiosperms but the gymnosperms are generally prominent in the hills but at one time in the history of the earth, there was greater dominance of the gymnosperms and were found as plentifully as the angiosperms of to-day.

The angiosperms are divided into **Dicotyledons** *i.e.*, plants which have two cotyledons in their seeds and **Monocotyledons** which have one cotyledon in their seeds. The example of the former is pea and of the latter maize.



Yeast—a fungus in a state of budding.

CHAPTER XXV

LIFE-HISTORY OF YEAST.

The plant belongs to the group of Fungi. It consists of a single cell sometimes remaining joined with one another forming a chain and often it separates and lives independently as a single cell. It is able to set up alcoholic *fermentation* in Saccharine solution. (Two species are generally found namely Saccharomyces cerevisiae and S. ellipsoideus. The last species is used for the preparation of wine from grape-juice) The plants generally float in air and specially near vine-yards and thrive well in sugary solution and can be found in toddy. The plant consists of a single cell, with cell-wall composed of fungus cellulose. There is a nucleus, vacuole and a number of oil globules.

Nutrition—

The nutrition is obtained from sugar-solution by direct absorption. The active agent extracted out of Yeast plants is zymase. The solution of sugar breaks down into carbon-dioxide (CO_2) and alcohol. The froth that is seen on the upper part of a vessel containing fermented liquid is due to CO_2 and the alcohol remains behind in the vessel.

The equation of the chemical reaction is:—

$$C_6 H_{12} O_6 = 2CO_2 + 2 C_2 H_6 O$$

Sugar　　　Carbon dioxide　　　alcohol.

The yeast-cell thrive well in the presence of oxygen but the transformation of sugar-solution is very meagre in comparison with the condition when oxygen is absent *i.e.*, more alcohol is produced in the absence of oxygen.

Yeast is able to *ferment sugar-solution.* Such a process where fermentation takes place by a living organism is spoken of as organised ferment. But an active agent has been extracted from yeast which is able to ferment. It is known as *Zymase.*

The significance of fermentation is peculiar in that it is a process of respiration. Ordinarily, respiration can take place only in the presence of oxygen, such a process is called aerobic respiration but there are plants like yeast which can decompose their complex food substances to liberate oxygen even in its absence with the help of ferments, such peculiar oxidative processes are called anaerobic respiration.

Reproduction—

Budding or Pullulation or Gemmation.

When there is plenty of sugar-solution, the yeast plant grows and divides by gemmation. At first, the nucleus divides and a projection appears on the cell which forms another yeast plant. A series of plants may be attached one upon another forming a chain.

Spore-formution—

Previously, it was thought that with the approach of unfavourable period, the yeast plant produced spores to tide over the period *i.e.*, when there was any want of the sugar-solution. The single cell produced four-nuclei, each of which collected some cytoplasm and formed spores. Generally, the number of spores was four. The structure containing the spores was called *Ascus*. The view was that the spores were formed parthenogenetically. Recently, Winge has shown that the spores are formed in yeast as a result of Conjugation. As regards the combination, he has shown various haploid cells conjugating to form the zygote. One thing which is to be noted is that the conjugating cells must be completely or almost full grown; young buds never conjugate. The spores come out of the ascus with the approach of favourable period and the wall of each spore bursts to form a new individual. The yeast goes on budding until the period for conjugation comes up.

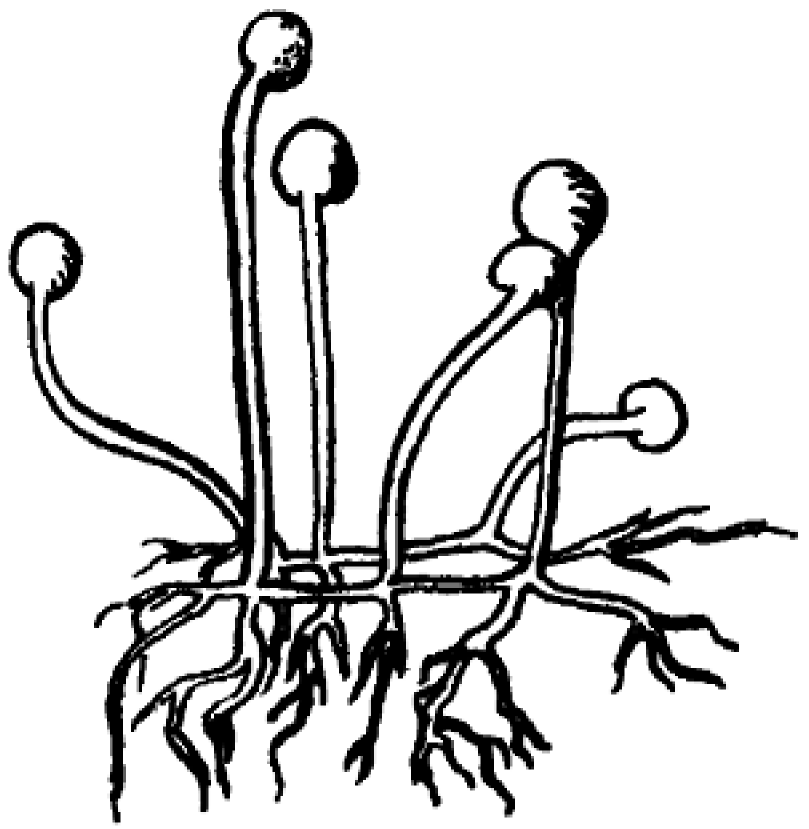
Mucor —

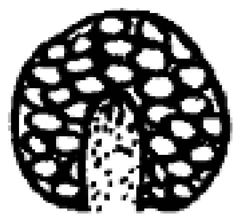
It belongs to the group of *Fungi* and are known as moulds. It is a saprophyte *i.e.*, lives upon dead organic matter. It is generally found as white patches on the surface of decaying organic matter namely on wet bread, dung and even on damp shoes but the colour ultimately changes to black. The plant consists of net-work of fine structures called collectively **mycelium** and the individual threads are known as **hyphae.** There is no partition-wall separating the cells but a number of nuclei are found. Such a structure is called coenocyte. The commonest forms are *Mucor mucedo* and *Mucor stolonifer.*

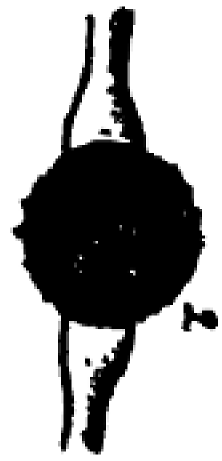
Asexual method of reproduction—

The individual threads or branches of the mycelium become erect and bear spherical sacs which are known as **Gonidangia** containing within them spores called

Gonidia. The gonidangium is also called Sporangium. The stalk of the *gonidangium* is called gonidiophore. The gonidiophore has a projection inside the sac which is called columella. This columella helps in the dispersal of the spores. When the *gonidangium* is mature, it bursts liberating the spores. Each spore or gonidium when free, puts out a germ-tube and forms a new mycelium. Recently it has been shown that the columella is a vacuolar structure and is formed by the union of vacuoles.


Mucor,


Sporangium.


Zygospore.

Sexual reproduction—

Sexual reproduction takes place as a result of *conjugation* of two similar gametes. Sexual organs are formed by the mycelium. The tip of the hypha is cut off by a partition and the protoplasmic contents form the gamete. The separated part containing the gamete is called the gametangium. The gamete has many nuclei so it is called coenogamete. By a similar process another gamete is formed, the two gametes fuse up forming a structure called zygospore. The zygospore has a thick warty wall consisting of two layers, the outer one is called exosporium and a delicate inner endosporium. After sometime which is a period of rest, the zygospore germinates and the exosporium is ruptured but from the endosporium another tube-like structure is formed which is called the promycelium. The promycelium bears a sac called the sporangium containing a number of spores. Each of the spores can produce a mycelium. Sexual reproduction in Mucor is remarkable in that it can take place only between two different **strains** of this plant. The two strains show no morphological difference, but there must be some physiological difference. They are referred to as the + and — strains. The only physiological difference so far recognised is that the + strain grows more vigorously. Two hyphæ from a + strain cannot fuse to form zygospores neither can two hyphæ from a — strain. Sexual reproduction takes place between a hypha of a + strain and a hypha of a — strain. Thus sexual reproduction is rare, since a + and — strain are not often found near enough to each other.

Sometimes the gametes instead of fusing with each other, can grow out into a *promycelium*. Such gametes which behave like zygospores are called azygospores.

Torula condition of Mucor—

The mycelium of mucor occasionally when placed in sugar solution divides into thin-walled cells called *oidium cells*. These cells are capable of budding and fermenting sugar solution like the yeast. This condition of Mucor is known as its **Torula condition.**

Spirogyra

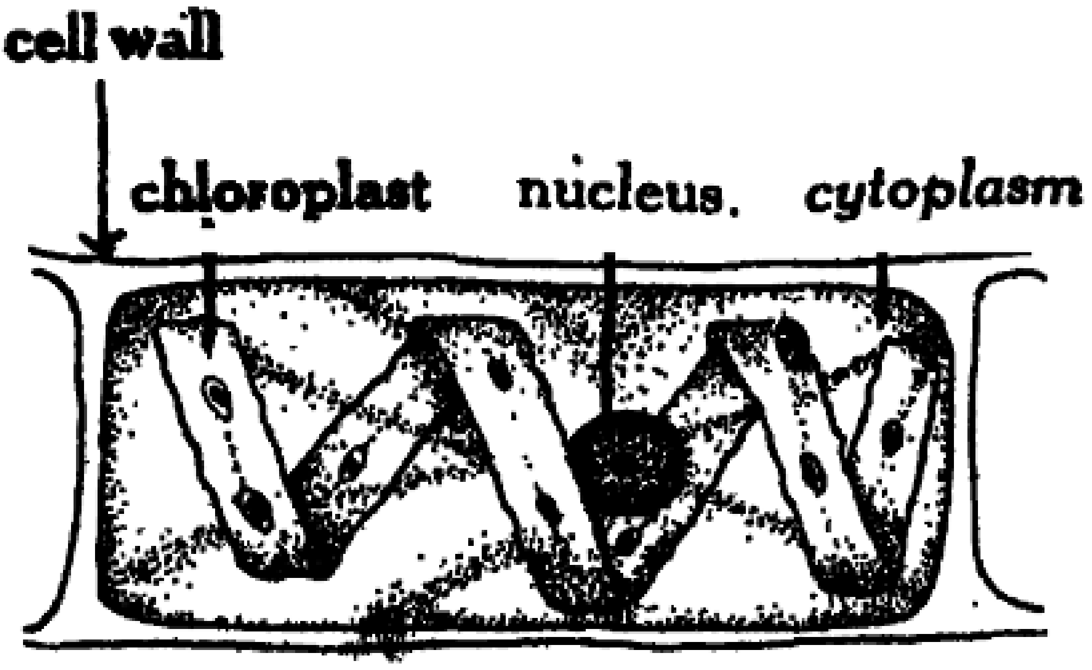
The plant belongs to the group of Algae. It floats as a mass of tangled threads in freshwater ponds and streams. The plants consist of a number of cells joined end to end sometimes having a mucilaginous covering. There is no distinction of base and apex of the plant as a number of equal cylindrical cells are joined to form a filament. Each cell of the filament has a distinct nucleus, the most characteristic *chloroplast* is in the form of a *ribbon* and the protoplasm generally recedes towards the wall and is known as primordial utricle. The band-shaped chloroplast may be 1 to 8 in number and each ribbon has a number of round bodies called pyrenoids. Pyrenoids are protein grains surrounded by starch grains. The filament can grow in length by the division and growth of the cells. Growth in length of the filaments takes place by the elongation of each individual cell and by the production of new cells by mitosis. This division usually takes place at night. Any cell is capable of division. This is known as **intercalary** growth as opposed to **apical** growth which takes place only at an apex.

Reproduction —

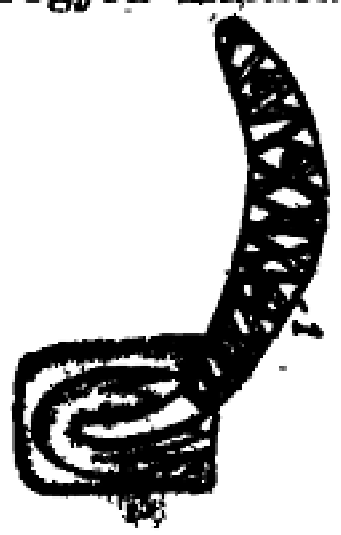
The cells of the filament can break up but at least one cell is required to form another new filament. This is called *Vegetative* method of reproduction.

Sexual reproduction takes place when two filaments come to lie side by side. The walls of opposite cells project and gradually increase in size and ultimately fuse up to form a tube-like structure called conjugation—tube.

Here the cells form the gametangia and the protoplasmic contents excluding the chloroplasts form the gametes.' Such a union between two gametes of the same kind is called *conjugation*. As a result of conjugation, the contents of one cell *i.e.,* one gamete travels towards the other gamete and fuses with it to form the zygospore. The zygospore passes through a period of rest after it has formed a hard wall. After the resting period, the outer coat of the zygospore ruptures and the inner contents grow out into a new filament.



A cell from spirogyra filament.



Spirogyra filament.

Zygospore germinates to form new filament.

When two different filaments lie side by side and conjugate, it is called **Scalariform** conjugation. Sometimes however, cells of the same filament may conjugate, in which case it is known as **lateral** conjugation. There is a slight physiological differentiation of sex; but the structural difference is not sufficient to warrant it being referred to as heterogamy or true fertilisation.

In some species, the gametes conjugate in the conjugation canal.

Sometimes the gametes without fusion can behave like zygospore. Such gametes are called azygospores and may be compared to a process of *parthenogenesis.*

Moss —

The moss plant belongs to the group of **Bryophyta** which is a step higher than the Thallophyta.

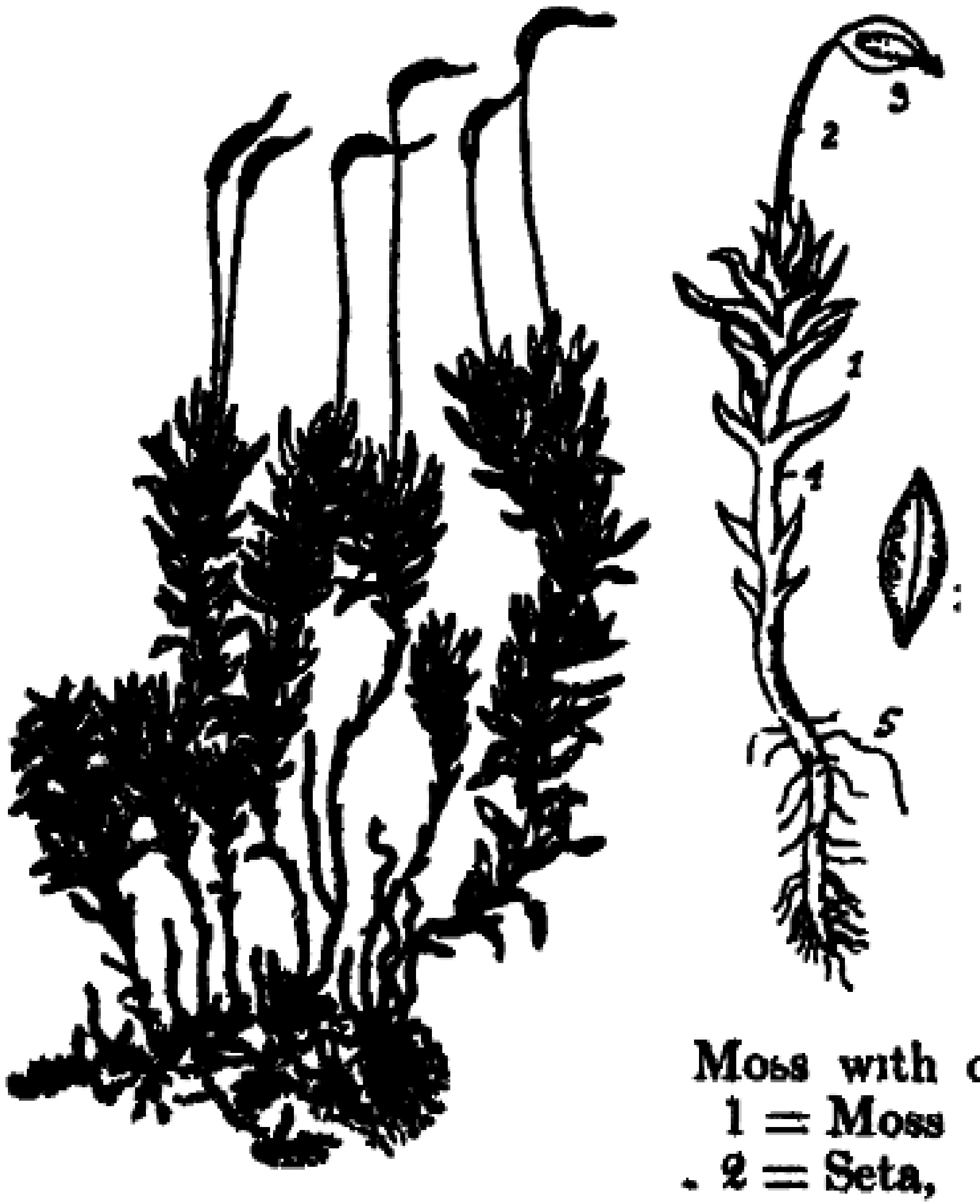
Mosses are abundant in the rainy season and generally grow as green velvety patches upon earth, rocks, tree-trunks, old walls and on the steps of ponds and streams.

General Characters —

The plants are very small scarcely attaining an inch in length. Leaves are thin, small and green in colour with a distinct midrib. The stem occasionally branches. There is no true root but a number of root-like structures are found at the base which perform the function of roots and are known as rhizoids which are multicellular.

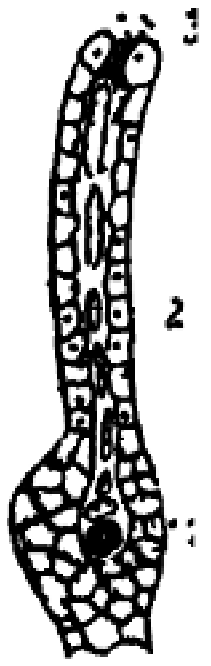
Life-History —

The life-history of the plant shows two distinct phases. Firstly, the ordinary green plant which ultimately bears the sexual organs is the gametophytic stage and secondly as a result of some sexual process another structure rises from the apex of the moss plant which bears the spores contained in a Sac-like structure. This represents the sporophyte-stage of the plant. Spores are produced within the sac and when mature, they come out and produce the moss plant but growing at first on a structure called **protonema.** Therefore a regular *alternation of sporophyte and gametophyte* is found in



1 = Leaf.

Moss with capsule
1 = Moss plant.
2 = Seta,
3 = Capsule.
4 = Stem.



1 = Ovum,
2 = Canal,
3=Archegonium

the mocsplant, which is described as alternation of generations. The gametophyte is also called the *gamobium* or sexual stage and the sporophyte is called the *agamobium* or asexual stage.

Anatomy of Stem—

A transverse section of the stem shows that it consists of an outer layer of epidermis followed by cortex of many—layered cells and a central strand of thin-walled cells called the conducting strand.

Anatomy of the Leaf —

The leaf consists of a number of cells containing chloroplasts *i.e.*, they are capable of manufacturing their food.

Reproduction —

(A) Vegetative reproduction.

(1) By buds,—leaf-buds may arise from any part of the plant, detach themselves and develop into new individuals.

(2) The protonemal filaments may be developed from some cells of the sporogonium.

(3) Some branches may separate to form new individuals.

(B) Sexual reproduction.

The sexual organs are generally borne at the apex of the stem among a tuft of small leaves. There are male and female organs called **antheridia** and **archegonia** respectively. The organs may be borne by the same plant when it is called *monoecious* or the organs may be found in separate plants when it is called dioecious *i.e.* moss plants are either monoecious or dioecious. Each antheridium is a club-like body borne on multicellular stalk. It has a wall consisting of a single layer of cells and a number of mother-cells for the male elements. Each mother-cell produces one antherozoid which is biciliate *i.e.* bears two cilia. Each archegonium is a flask-shaped body containing a female cell within it called the oosphere. There is a neck of the archegonium which forms a canal at the time of union of male and female cells. The canal has a mucilaginous secretion rich in cane-sugar which seems to attract the antherozoids but only one is allowed to fuse with the oosphere. This process of fusion is called fertilisation. As a result of fertilisation, the oosphere is converted into oospore and it receives a stimulus of growth and forms another structure which is called the sporogonium of moss.

The sporogonium has a stalk called seta and an upper ovoidal head called the capsule. The capsule has a special tissue within it which is called the archesporium or the spore-producing tissue which becomes evident on a longitudinal section of the capsule. The central tissue of the capsule is called columella. It has a cap-like upper portion called operculum connected with columella by annulus. There is a tooth-like portion near the annulus called peristome which helps to disperse the spores by absorption of water.

When the capsule is ripe, the upper portion of the sporogonium which might carry the remnants of the neck-portion of the original archegonium is thrown off and the spores come out. Each spore can germinate and produce a filamentous structure called protonema. The moss plant arises as a bud on this protonema.

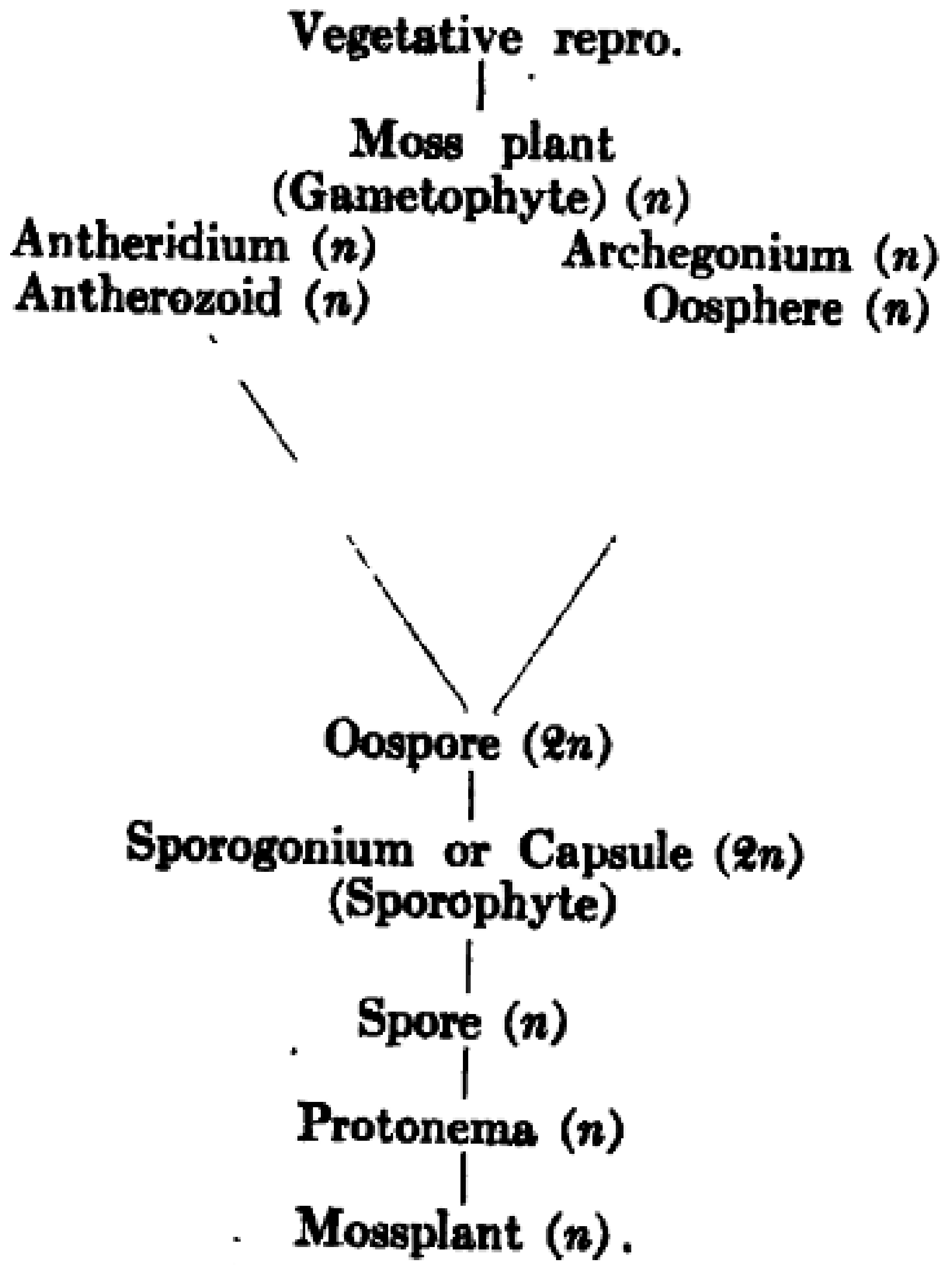
The Life-Cycle of a Moss.—The life-cycle may be summarised in a few brief statements:—

1. Germination of the spore results in a branched filamentous, alga-like growth called the protonema.
2. The formation of special protonema branches, and the setting of an apical cell at the end of each branch.
3. The growth of each of these branches or "buds" into a stem bearing rhizoids at the lower end and simple spirally arranged leaves above.

4. The formation at the tip of some of the leafy shoots of groups of antheridia and paraphyses.
5. The formation at the tips of other shoots of groups of archegonia and paraphyses.
6. The opening of antheridia and archegonia during a period when the plants are wet and the escape of the sperms.
7. Swimming of some of the sperms to the archegonia whither they are probably directed by certain substances which diffuse outward from the open archegonia.
8. Fertilization, followed by the formation of a cell-wall about the zygote. The zygote nucleus and all the nuclei of the sporophyte generation have $2n$ chromosomes.
9. The development of the zygote by growth and cell divisions into an embryo sporophyte which is enclosed by the enlarged archegonium venter (calyptra) until just before the maturity of the sporophyte when the calyptra is torn away from its attachment to the leafy shoot.
10. The development of the embryo into the mature sporophyte consisting of (*a*) the foot which penetrates the tip of the stem of the gametophore and serves as an organ of attachment and absorption, (*b*) the seta or stalk and (*c*) the capsule, a complex structure within which the spore mother cells are produced but which is mostly made up of sterile tissue.
11. The two successive divisions of each spore mother cell to form a tetrad of spores. The first division of the spore mother cells is a reduction division and marks the end of the diploid or sporophyte phase and the beginning of the haploid or gametophyte phase in which all the nuclei have n chromosomes.
12. The drying out of the capsule, the loss of the operculum or capsule cover, and the escape, assisted by the hydroscopic movements of the peristome teeth, of the spores.

According to true cytological data, the spore starts the gametophytic stage (n chromosomes) upto the formation of zygote (oospore) ($2n$ chromosomes) which is the starting point of the sporophytic stage.

Graphic representation of the life-history of Moss.



Fern :—

The ferns belong to the group of **Pteridophyta.** Ferns are generally known as Filices or Filicales.

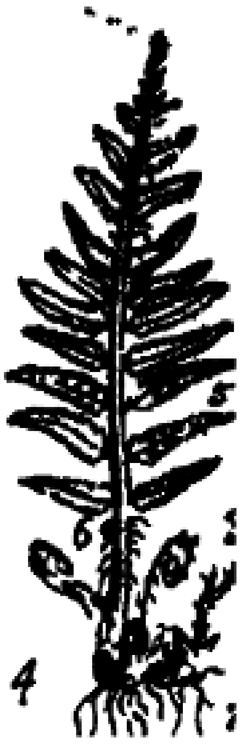
Habitat : Generally it grows on damp places and is more or less shade-loving. The plants are rhizomatous herbs, but in tropical countries large tree-ferns like palms are found. The temperate climate is suitable for its growth because the hills of Darjeeling, Simla and Kashmir are famous for their luxuriant growth of ferns. In cities, the ferns adorn the gardens and palaces of the rich. People take a fancy for some ferns as for example, the maiden-hair fern is invariably associated with the handiwork of florists. The narrow water-ways of Bengal are provided with a good variety of ferns specially the shady lands through which the water courses its way.

The plant is a small herb with an underground rhizome. The leaves are generally compound and of the pinnate type although the palmate type is also found. In some ferns, the leaves are simple. Sometimes ferns are found as epiphytes *i.e.*, growing upon another plant and live upon air. The plant is covered all over by hair-like structures called ramenta. The leaves are green in colour and provided with distinct midrib and veins. The ordinary leaves are called fronds or **trophophylls** whereas spore producing leaves are **sporophylls.** The ptyxis of the leaf is circinate *i.e.*, rolled up in the young condition like a dog's tail. Roots are found in ferns but are adventitious. It takes about two years for the maturation of a leaf but usually a number of leaves open every year. The leaves bear some globular bodies on the undersurface which are either on the veins, or on the margins or on surface. These bodies are known as sori. Each **sorus** consists of a number of sac-like structures called sporangia. Each **sporangium** is stalked and rises from a tissue of the leaf called placenta. The sporangia are protected and covered by a structure called **indusium.** The sporangium has a wall called **annulus** with a weak spot called **stomium.** The spores are found within the sporangium, the number is about 64. When the sporangium is mature the spores come out through the stomium. The spore is a minute one-celled reproductive unit having its wall differentiated into two parts called exosporium (outer) and endosporium (inner). Each spore can germinate and ultimately by celldivisions forms a heart-shaped structure called the **prothallus.** This prothallium is a thin, green, multicellular body bearing a number of rhizoids on the undersurface. These rhizoids draw nourishment from the soil. The rhizoids are unicellular. The prothallus has a notch at the upper part and this prothallus represents a definite stage in the life-history of fern. The prothallus on the underside bears two kinds of *sexual organs*, the *antheridia* and the *archegonia*. The antheridia are found at the base together with the rhizoids whereas the archegonia occur near the notch. This is the **gametophyte** stage of fern. Each archegonium is shaped like a flask and consists of a basal portion called the venter completely placed in the tissue of the prothallus and a neck. The venter has a single female gamete called oosphere or ovum and above it a ventral canal cell and the neck consists of four-rows of cells. Just above the ventral canal cell is a single neck canal cell. The neck is at first closed but at maturity opens and due to the disorganisation of the canal cells a mucilaginous secretion comes out which is rich in *malic acid* to attract the male elements or antherozoids.

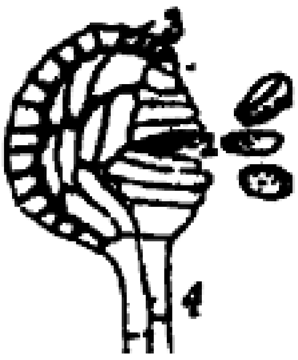
The male organ or antheridium is a capsular body. The capsule contains a number of the mother-cells of the antherozoids. One antherozoid develops in each cell. Ultimately the antherozoids are set free and they move towards the neck of the archegonium. The antherozoid has got swimming capacity owing to the presence of a number of cilia on its body. Therefore the antherozoids are multiciliate. One of the antherozoids attracted by the secretion of malic acid fuses with the oosphere, nucleus with nucleus, cytoplasm with cytoplasm and forms the oospore. This process is called fertilisation. The process of fertilisation generally takes place between

Fern.

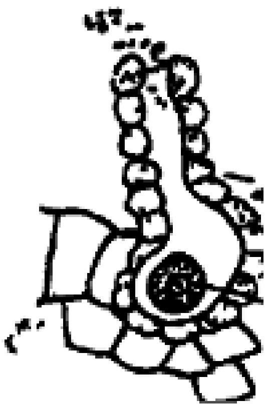
antherozoid produced by one prothallus with the oosphere produced by another prothallus *i.e.,* cross fertilisation takes place although the prothallus of fern is hermaphrodite, the sexual organs of the same prothallus do not mature at the same time and thus it favours cross-fertilisation



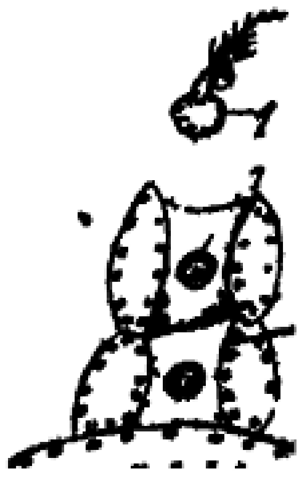
1 = Leaf,
2 = Root,
3 = Circinate,
4=Rhizome,
5 = Leaf



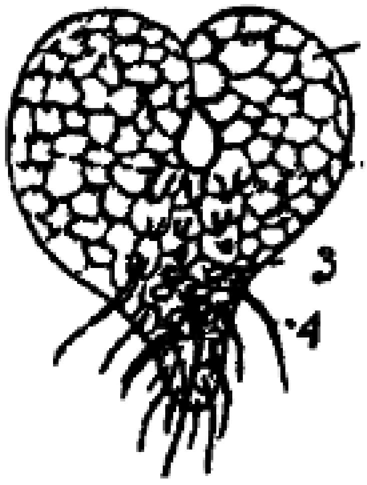
1 = Spore,
2 = Stomium,
3 = Annulus,
4 = Stalk



1 = Ovum,
2 = Archegonium



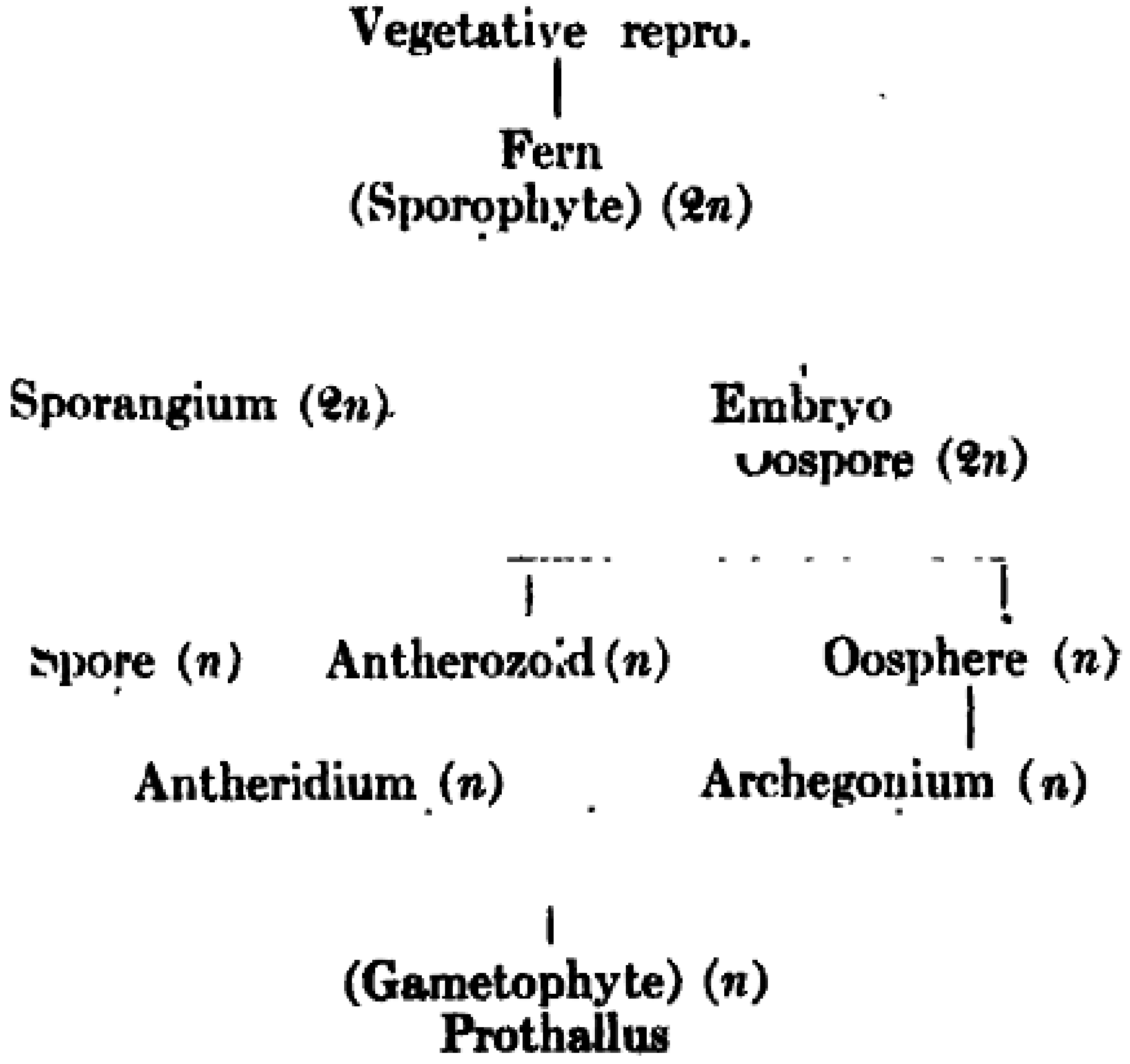
1 = Antherozoid
2 = Mother cell



1 = Prothallu
4 = Rhizoid.

The oospore continually divides and segments forming the primary root, first leaf or cotyledon, stem and a massive foot. The foot absorbs nutrition for the developing embryo until it becomes independent and absorbs moisture from the soil. The primary root is replaced by a number of adventitious roots. The prothallus in the meantime dries up and the plant becomes an independent organism to all intents and purposes.

Graphic representation of the Life-history of *Fern*.



Alternation of generations—

The life-history of ferns shows two distinct stages or Phases. The plant itself is the sporophyte and before another sporophyte is formed, there occurs the gametophyte in the form of prothallus. The prothallus is quite independent and manufactures its own food. Therefore the sporophyte is followed by the gametophyte and then another sporophyte. Such a phenomenon is called alternation of generations. The gametophyte is the sexual phase and sporophyte is the asexual phase of the plant.

Apospory and Apogamy—

The fern-plant often adopts the process of vegetative reproduction by producing another fern-plant from the surface of the leaf which is known as bulbil or from rhizome or from a part of the leaf.

In some cases, the fern-plant arises without the spore stage or the sexual process is eliminated. The former is called apospory and in such cases the prothallus may directly develop from the sporangium or from any portion of the frond. In apogamy, the ordinary cells of the prothallus can give rise to the fern-plant.

Anatomy of rhizome—

A transverse section of the rhizome shows a number of vascular bundles arranged in the ground tissue. There is hypodermal sclerenchyma and on the outside is the epidermis. Each vascular bundle consists of xylem in the centre surrounded by phlœm. The phlœm has on the outside, a circle of pericycle and a layer of endodermis. There are some smaller bundles which pass on to the leaves.

The section of petiole is similar to rhizome but the stele is like a horse-shoe.

Pea—

The pea plant belongs to the group of Dicotyledons under angiosperms. The plants are delicate herbs. The stem is soft. The leaves are compound and of the pinnate type and each leaf has a number of leaflets.

The ultimate leaflets are modified into tendrils. At the base of the compound leaf there are leaf-like structures which are the foliaceous stipules. The root is of the dicotyledonous type *i.e.,* a primary root branches and produces a branch system of roots. The roots have a peculiar property of fixing nitrogen of the atmosphere with the help of nitrogen-fixing bacteria which are found in the form of swellings or tubercles on the roots.

Flowers are in racemes. Each flower has four whorls. The first and outermost whorl is the calyx forming a tube by the union of the sepals. The calyx is gamosepalous. The number of teeth is five. The next whorl is the corolla, consisting of 5 petals, and is of the *papilionaceous* type. The corolla is polypetalous. Of the five petals, the posterior one is the largest and is known as the Vexillum or standard. There are two petals on the two sides called Alae or Wings. On the anterior side, two petals are united to form a boat-shaped structure called keel or carina.

The third whorl is the andraecium consisting of ten stamens, of which nine are united and one is free. The stamens are di-adelphous. The fourth whorl is the gynoecium or pistil. The gynoecium is monocarpellary *i.e.,* consists of one carpel. The ovary is superior. The fruit is a *legume*. The seeds are *exalbuminous*.

Maize—

The **maize** plant belongs to the group of Monocotyledons under angiosperms.

The plants are stout herbs with solid stem. The nodes and internodes are solid. The leaves are simple, with sheathing leaf-bases. The roots are fibrous or adventitious.

The inflorescence is in the form of spikelets. Male flowers and female flowers are found on separate spikelets on the same plant *i.e.,* monoecious. Male flowers occur on the top and female flowers lower down on the stem. Male flowers are two in each *spikelet,* of which one is sessile and the other flower is pedicelled. Each flower has four glumes, of which the first and second glumes are empty. The third and fourth glumes are hyaline, paleate and enclosed by the first one. The perianth is represented by two fleshy lodicules. Stamens are three in number. Anthers are versatile.

Female spikelets are one-flowered and are arranged on a fleshy rachis. The ordinary "Bhutta" represents so many flowers arranged on the axis of an inflorescence. There are four glumes of which the first two are broad, the third one is empty and the fourth is two-fid. Perianth is not represented, and even the lodicules are absent. The ovary is superior with long thread-like two-fid styles. Fruit is a *caryopsis.* Seeds are *albuminous* and the axis of the embryo is situated at one side of the seed.

CHAPTER XXVI

INTRODUCTION TO THE GENERAL CLASSIFICATION OF ANIMALS.

There are various types of animals on the face of the Earth, too numerous to be counted upon, so they are grouped into convenient divisions called **Phyla.** The whole kingdom is sometimes divided into **Protozoa** or **unicellular** animals and **Metazoa** or **multicellular** animals. The **Protozoa** consist of a single cell which performs all its functions through this cell; example Amœba, Monocystis, Malarial parasite etc. The **Phylum Protozoa** again is divided into a number of **classes** called **Rhizopoda** *e.g.,* Amœba; class **Flagellata** *e.g.,* Euglena, class **Ciliata** *e.g.,* Paramœcium and class **Sporozoa** *e.g.,* Monocystis.

The other group Metazoa is a vast group and includes all multicellular animals. The Metazoa is again sub-divided into **Porifera, Coelenterata** and **Coelomata.** The Porifera includes sponges with two body layers Ectoderm and Endoderm and hence they are termed Diploblastica. The Coelenterata is also two layered and includes the Hydra and the Obelia. The body-cavity of the Cœlenterata is known as the Cœlenteron.

The Cœlomata includes all animals from the **Annelids** like Leech and Earthworm to the highest group like the **Mammals.** It is better to adopt the following classification in order to have a bird's eye view of the

The Chordata and the Invertebrata are divided into the following phyla :–

- Phylum Chordata
  - Acrania (without skull)
    - Subphylum Cephalochorda *e.g.* Amphioxus.
    - Subphylum Hemichorda *e.g.* Balanoglossus.
    - Subphylum Urochorda *e.g.*, Tunicates.
  - Subphylum Vertebrata or Craniata (with skull).
    - Without true jaws, Cyclostomata *e.g.*, Lamprey.
    - With true jaws.
      - Class 1. Pisces.
        - Sub-class Elasmobranchii *e.g.*,Sharks
        - Teleostei *e.g.*, Bony Fishes, Bhetki, Rohu etc.
      - Class 2. Amphibia *e. g.*, Frogs, Toads, etc.
      - Class 3. Reptilia *e.g.*, Snakes, Lizards, Crocodiles, etc
      - Class 4. Aves *e.g.*, Birds.
      - Class 5. Mammalia *e.g.*, Guineapig Cat, Dog, Tiger, Man.

- Invertebrata
  - Phylum Protozoa *e.g.*, Amœba Monocystis.
  - Phylum Porifera *e.g.*, Sponges.
  - Phylum Cœlenterata *e.g.*, Hydra.
  - Phylum Platyhelminthes *e.g.*, Liver Fluke.
  - Phylum Nemathelminthes *e.g.*, Round worms.
  - Phylum Echinodermata e.g., Star-fish
  - Phylum Arthropoda *e.g.*, Prawn.
  - Phylum Mollusca e.g., Fresh-water mussel, Snails and Slugs.

whole animal kingdom. The animals are broadly divided into **Vertebrata** and **Invertebrata.** Animals without a vertebral column or a notochord come under the group **Invertebrata** or **Non-chordata,** while those possessing a **vertebral column** or **Notochord** are designated **Vertebrata** or **Chordata.** Both these groups are again divided into several phyla.

The chordata and the Invertebrata are divided into the following phyla :—

The Chordata are similarly divided into several subphyla and classes. The following scheme will enable the student to grasp the subject more easily than the usual long description found in the textbooks.

The chordata have some lower groups like Balanoglossus where the Notochord is confined to the neck region. In Tunicates the Notochord is confined to the larval condition. In the Amphioxus the Notochord persists from one end of the body to the other. In the Vertebrata or Craniata there is a bony case for the Brain called the Cranium whereas it is absent in the Acrania. The higher chordates show the development of jaws as organs of mastication.

The mammals are again sub-divided but it will suffice for the Intermediate course students to remember that it is a class of the Vertebrata and are specialised with the nursing of their young with breast milk in the early stage of life.

The **invertebrata** are characterised by :—(1) Absence of vertebral column, (2) Nervous system with ventral cord generally, (3) Heart when present is very rudimentary. (4) **Body-cavity** either cœlenteron, haemocoele or coelome.

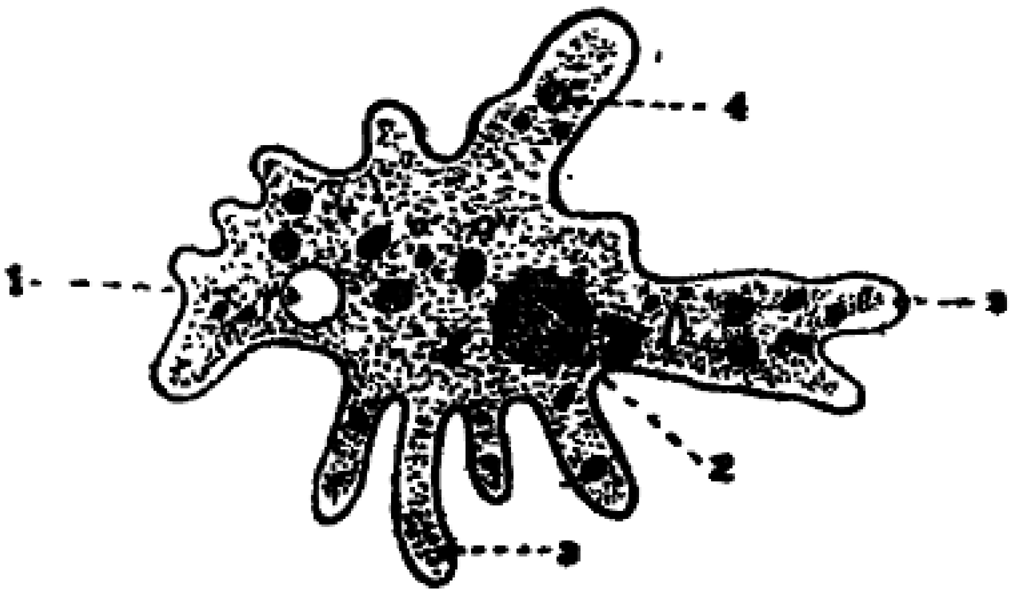
The **vertebrata** have (1) Dorsal nervous system, (2) Ventral heart, (3) **Vertebral** column, (4) Respiratory organs like gills or lungs.

CHAPTER XXVII

DETAILED CONSIDERATION OF SOME TYPICAL ANIMALS.

The Amoeba.

The Amœba is the smallest animalcule known. It belongs to the phylum **Protozoa.** The animal is unicellular. The cytoplasm is differentiated into an outer clear **Ectoplasm** and an inner granular **Endoplasm.** There is a **Nucleus** with a **Nucleolus.** There are some round bodies called **food vacuoles** in the cytoplasm. There is another large vacuole called **Contractile Vacuole.** This single cell performs all the functions of an animal. The animal generally lives in the mud of ponds, tanks and ditches of our country and are often attached to the waterweeds. One species lives as a parasite in human beings and causes Dysentery. The size of the animal is about 1/100 of an inch. It is not seen with the naked eye but is visible with the help of the microscope.



1—Contractile vaculoe, 2—Nucleus, 3—Pseudopodia, 4—Food vacuole in endoplasm.

Movements :

The animal moves by sending out protoplasmic processes called **Pseudopodia.** The animal is ever changing its form by means of pseudopodia. At one moment it has a particular form, the next moment it changes its form by thrusting out other pseudopodia. Firstly the Ectoplasm flows out and then the Endoplasm follows to form the pseudopodium.

The movement is carried out by the protrusion of a pseudopodium and the whole mass of protoplasm flows into it. Next moment another pseudopodium appears and the movement of the animal is thus carried on. The animal is called **Proteus Animalcule** on account of its everchanging form.

Nutrition :

The Animal Amœba feeds on small organisms *viz.*, microscopic plants and animals. The pseudopodia encircle the food and gradually incorporate it in its own protoplasm. As soon as the food comes into the protoplasm, a drop of water is secreted round it and the food is digested. The reaction of the secretion is at first acid and then alkaline. The secretion kills the food (mainly living microscopic organisms) and the wasteproduct after digestion is over, is simply left out when the animal moves away from the particular place. In Amœba digestion takes place within the cell. This is called **Intracellular digestion.** The animal digests the food within the food vacuole. The food consists mainly of proteins and carbodydrates, but not of fat, it is said.

Irritability, Automatism & Conductivity :

The Amœba is **irritable,** automatic and conductive. The **irritability** is not situated in the special sense organs but if an electric shock be passed into a drop of water with amœba in it, it will withdraw its pseudopodia and contract. Its conductivity is seen when it is pricked by a fine thread of glass or when it is brought in contact with solutions of salt, sugar or acids. It moves away. The **conductivity** is proved by the fact that a pseudopodium is formed at a point other than the actual point of stimulus. It moves away from strong light. There are some actions of the amœba which are not referable to any stimulus but takes place from within the animal and are known as **Automatic.**

Excretion and Respiration :

The whole body of the animal comes in contact with water so the discharge of waste products can take place throughout the body of the animal as also Respiration. It breathes, that is, absorbs oxygen and gives off CO_2 from all over the body. There is a contractile Vacuole in the animal which discharges the water which enters throughout the body of the animal and the water which has accumulated as a result of metabolism is discharged containing the waste products. The Carbon dioxide collects in the contractile vacuole and is passed out by it. Therefore, the contractile vacuole acts both for excretion and for respiration.

Depression :

Sometimes due to unfavourable conditions the animal undergoes depression. The nucleus becomes larger and all the functions of the body are almost brought to a standstill.

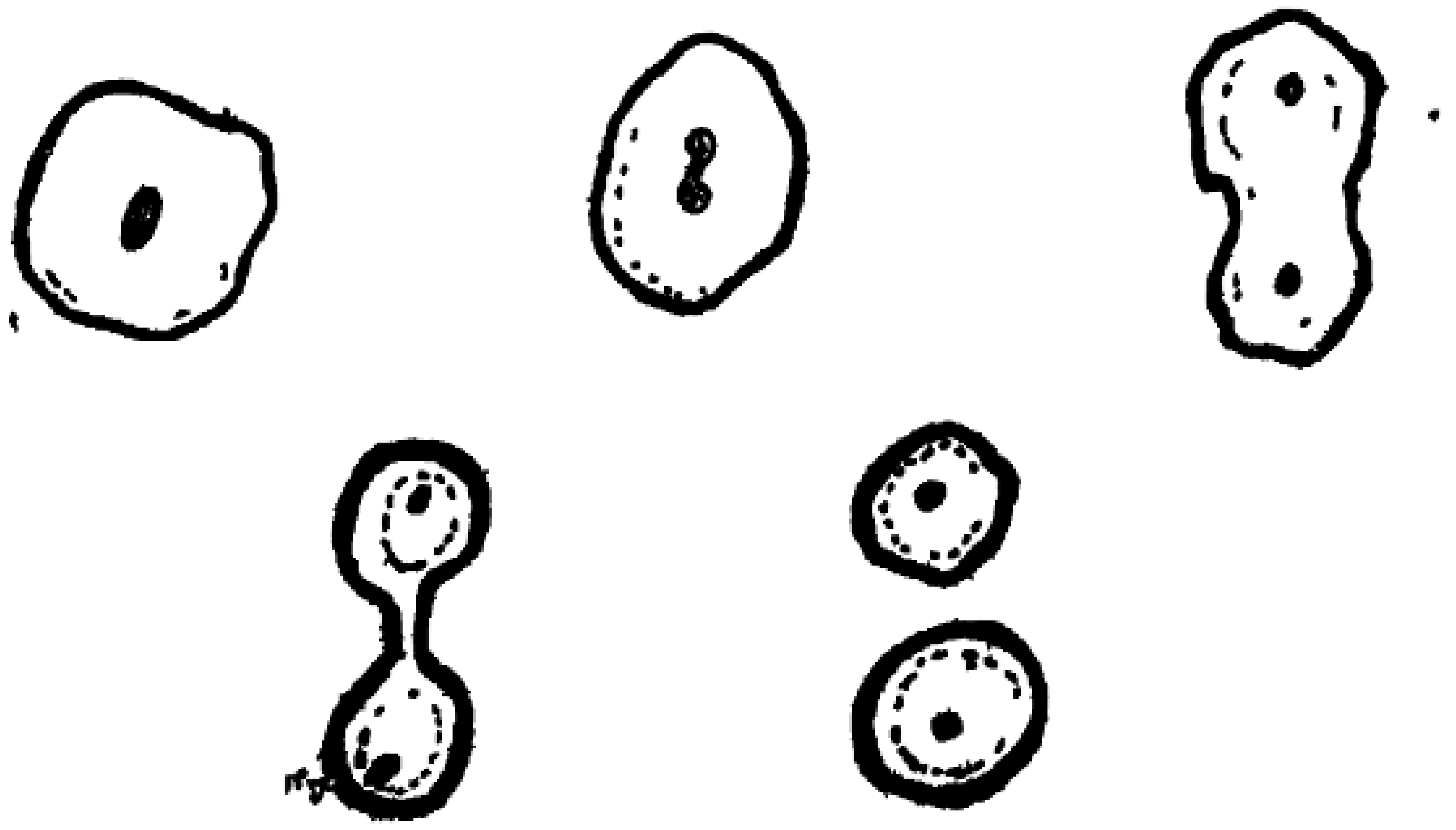
Encystment :

The Amœba sometimes withdraws its pseudopodia and forms and secretes a wall round it called the Cyst. This is called its Encysted condition. This takes place due to unfavourable conditions either the water in the pond dries up or is frozen. The approach of favourable period means the activity of Amœba and the cystwall breaks and normal life is resumed.

Reproduction :

There are two kinds of reproduction in Amœba (1) **Binary fission** and (2) **Multiple fission.**

Binary fission—The animal simply divides into two. First the nucleus divides and then the cytoplasm divides to form the daughter amœbae. Sometimes the nucleus



Binary fission of Amœba.
Nucleus divides into two and the cytoplasm too forming two amœbæ.

divides by Mitosis, the cytoplasm constricts in the middle and forms two individuals. The nucleus always divides before the body of the cell divides.

Multiple Fission :—The amœba becomes encysted and the nucleus automatically divides into a number of nuclei. The nuclei move towards the surface and collect a bit of cystoplasm. The cystwall breaks and the individual escapes as spores with pointed pseudopodia. Each such spore develops into a new amœba.

Thus an amœba while enclosed within the cyst breaks up into a number of rounded structures which are ultimately liberated by the breaking of the cystwall and each one becomes a minute independent amœba. This process is called **Sporulation** and the structures that give rise to new amœba are called spores.

Plastogamy :

Sexual reproduction has not yet been provided in amœba. Sometimes a number of amœbae fuse and thereby form a mass of protoplasm containing many nuclei. This mass is known as plasmodium and the process is known as plastogamy.

Thomson says that **conjugation** has been observed in amœba.

Monocystis : V. V. Imp.

This animal is also microscopic in size, unicellular in structure and belongs to the group of Protozoa. The Protozoa is sub-divided into a class called **Sporozoa** which live as parasites inside the bodies of various animals. Parasites are animals that live upon other animals, rob the host of its nutrition, sometimes even destroy and eat the tissues of the host and ultimately killing it. Monocystis is a parasite which lives in the seminal vesicles of the Earthworm. When an Earthworm is cut open, certain white lobed organs known as sperm-sacs are found at its anterior end. Inside these organs the sperms of the worm undergo development and the Monocystis lives and passes through the various stages of its life-history within the Spermmother cells of the worm. Monocystis lives upon the fluid nutrition meant for the Spermatozoa of the Earthworm

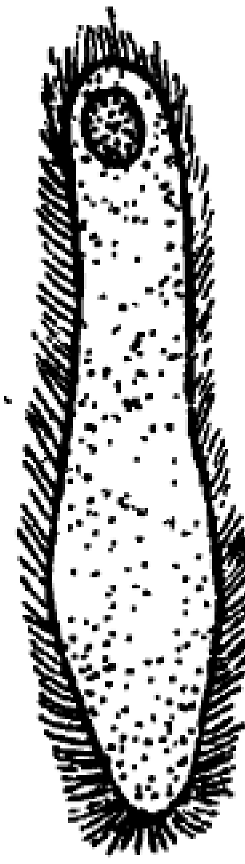
The life-history of the Monocystis is divided into three stages called **Trophozoite, Gametocyte** and **Sporozoite.**

The Trophozoite Stage :

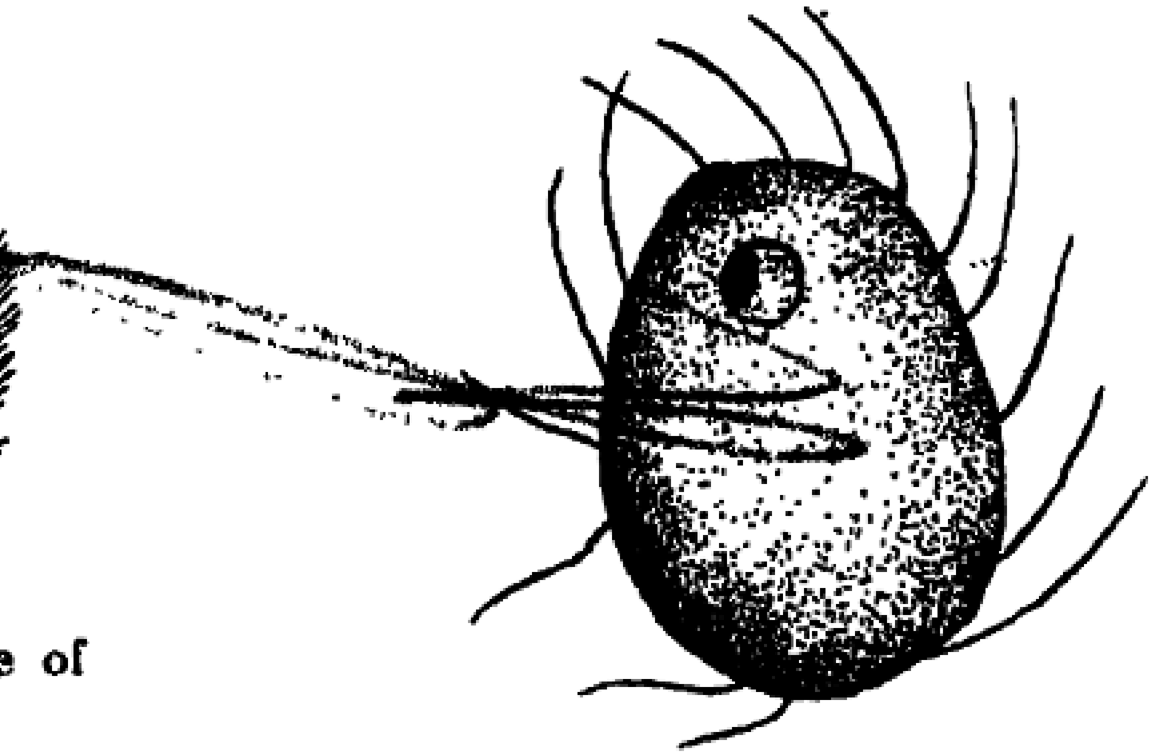
The ordinary animal is the **trophozoite.** The full grown adults are visible to the naked eye—flattened worm-like cells ; the shape alters during the sluggish movements. Peripherally there is a porous cuticle, a clear corticalzone and a network of myoneme fibrils. Each trophozoite has an elongated body, the outer portion is the Ectoplasm and the inner medullary portion is the Endoplasm. The Endoplasm contains a spherical nucleus with nucleolus The Ectoplasm has an outer cuticular portion. There are fine fibres in the ectoplasm composed of myonemes which carry out a series of wave-like undulations in the body of the trophozoite. There is no mouth, no contractile vacuole, fluid nutriment being absorbed from the cells of the host by the whole body of the Monocystis.

The Gametocyte Stage :

Reproduction—Two trophozoites come to meet each other and are covered by a common double cyst wall

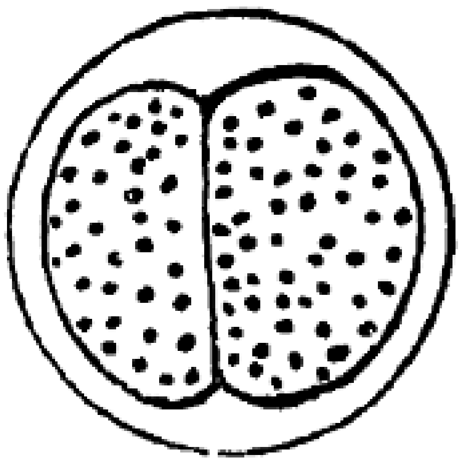


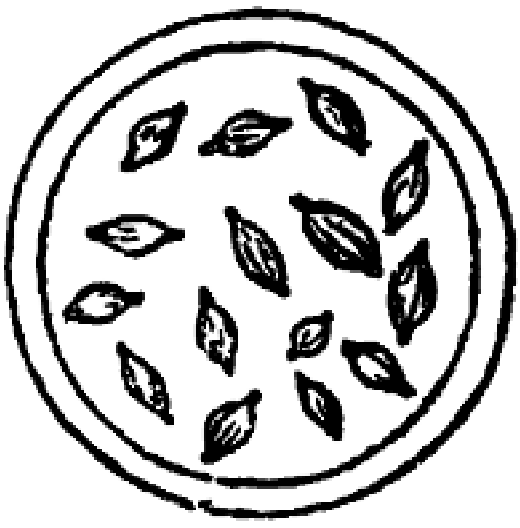
Trophozoite of Monocystis. The ectoplasm is covered with the tails of the sperms of earthworm.

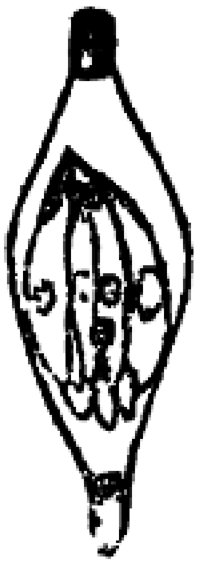


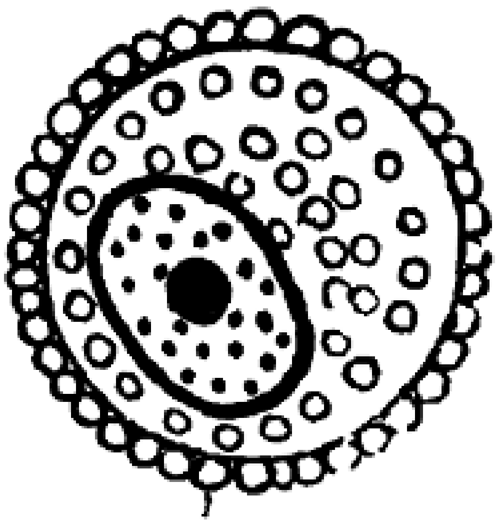
Trophozoite.

which is secreted. Now each is known as a Gametocyte. In the Gametocytes the nucleus of each divides into a number of nuclei. Each nucleus collects some cytoplasm and forms a gamete. So that some gametes are formed in both gametocytes. The partition-wall disappears and the gamete of one unites with the gamete of the other. Therefore gametes are derived from separate parents. This is called Cross Conjugation. As a result of union of two gametes a zygote is formed. This zygote is known as a Sporont. It secretes a boat-shaped horny case and is known as a **Pseudonavicella.** The cyst at this stage contains a number of such boat-shaped spores.


Gametocyte


Sporozoite


Pseudonavicella.


Trophozoite.

The Sporozoite Stage :

The nucleus of the zygote undergoes division within the cyst into eight sickle-shaped bodies called Sporozoites. Each sporozoite will enter a fresh host and assume the trophozoite condition. But generally the Earthworm dies when the sporozoite condition is reached. The dead earthworm mixes with the soil and when the soil is eaten up by some fresh Earthworm, it makes its way up into the seminal vesicles and gradually reach the trophozoite condition. There are certain worm-eating birds and if they happen to eat an infeceted earthworm the cyst remains intact in the alimentary tube of the bird. But the cyst dissolves in the alimentary tube of the fresh living earthworm which has eaten it due to the action of the digestive juices there, and the Sporozoite enters the seminal vesicle of the animal.

The body of the trophozoite is sometimes covered with cilia but these tails really belong to the sperms of the earthworm whose main part has been absorbed by the parasite. The covering of cilia only adheres to the body of the trophozoite, there being no organic connection with it.

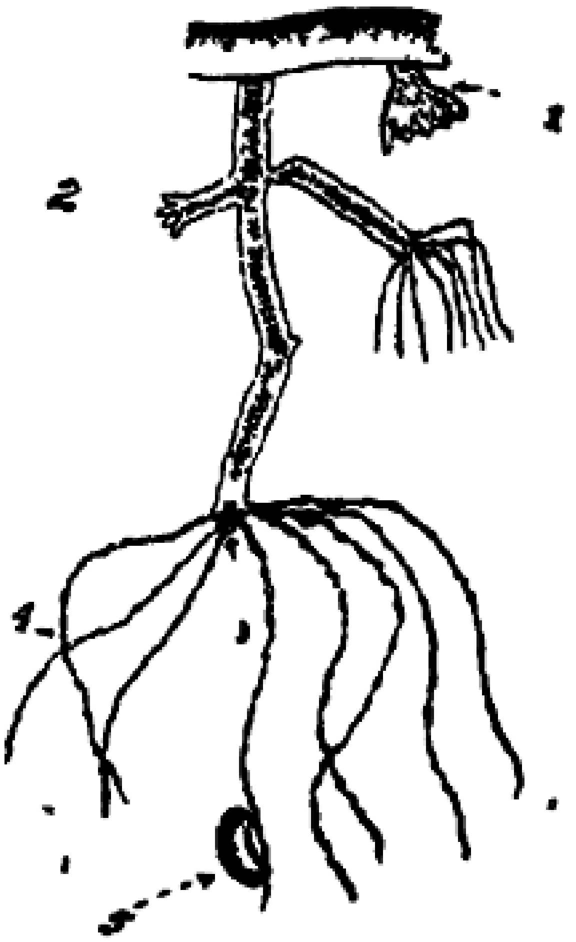
Thus the life-history of the Monocystis is completed in three stages.

Hydra :

The Hydra or fresh water **Polyp** is composed of numerous cells, so it is a Metazoa in contrast with Protozoa which are composed of single cells. All animals above the Protozoa are known as Metazoa. The Hydra belongs to the group of small animals called **Coelenterata.** The Cœlenterata have only one set of spaces within, which all communicate with each other and with the exterior through the mouth. The shape of the animal is that of a minute cylinder. The base or foot is attached to some surface generally weeds whilst the other extremity carries a circle of delicate thread-like appendages called **Tentacles.** The hollow space of the animal is called the **Coelenteron** or **Enteron** lined by Endoderm Cells. The body of the Hydra consists of two layers of cells called **Ectoderm** (outside) and Endoderm (inside) with a middle structureless lamella between the two layers called **Mesogloea.** Hydra is a member of the group of Cœlenterata which have the following peculiarities :—

(1) The animals are called **Diploblastica** because the body is composed of two layers called **Ectoderm and Endoderm.**

(2) The body of the animals has a single space called Cœlenteron. There is a single aperture of the Cœlenteron *e.g.,* the mouth.



1—New hydra in the form of bud, 2—Bud, 3—Mouth, 4—Tentacle, 5—Water-flea.

Hydra.
1—Mouth, 2—Hypostome, 3—Bud, 4—Tentacle, 5—Bud.

(3) There is a lamella between Ectoderm and Endoderm called Mesogloea.

(4) Nervous system is in the form of cells.

(5) Reproductive organs are developed either from Ectoderm or from Endoderm.

Functions of the Cœlenteron :—

(*a*) Digestion is carried on in the Endodermal cells. There are **intercellular** and **intracellular** digestion. When digestion takes place outside the cells of the Endoderm (inter) or when digestion takes place within the cells of the Endoderm (intra).

(*b*) The residue left after digestion passes out through the mouth.

(*c*) Respiration and excretion take place to some extent from the Endoderm cells.

Habitat :

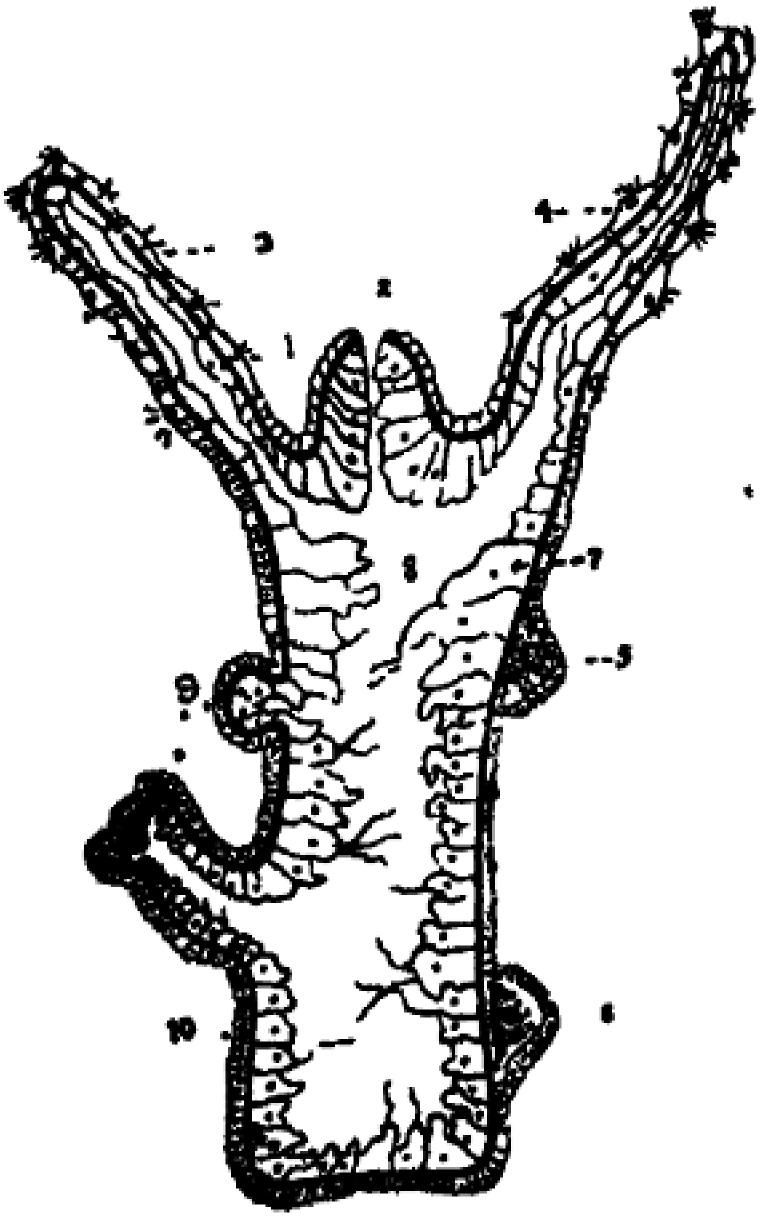
Hydra lives in fresh water attached to some weeds. If some weeds be kept in a glass jar, Hydra aggregate at the base of the jar or they attach themselves to the sides of the vessel. They are brown or white in colour. The species common in Bengal is the Hydra Vulgaris. If the animal be undisturbed it is found to attach itself by the base and the free end shows half-a-dozen threads called tentacles. The animal lives on waterfleas. The water-flea touches the tentacle and is forthwith stunned. The water-flea may be caught by the tentacles and sent to the mouth or the water-flea goes away and recovers from the effects of stunning imposed by the tentacles.

Shape :

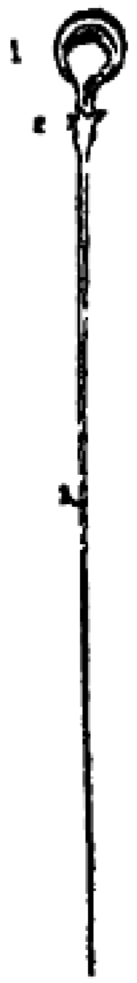
The body of the Hydra is like a hollow cylinder with a ring of hollow tentacles surrounding the mouth. The other end is the base of the animal. The mouth is placed on a raised structure called "**Hypostome**" or **Oral cone.** The mouth leads into the only space of the body called Cœlenteron or Enteron. The hollow space inside the tentacles is continuous with the Enteron. The body of the Hydra is pointed and consists of an outer Ectoderm and an inner Endoderm. There is a structureless lamella between them and is called Mesogloea which is secreted by those cells.

Ectoderm :

The Ectoderm cells are more or less conical in shape. The first type of Ectoderm cells is known as **musculo-epithelial** cells. These cells have their broad ends on the outer side and form a continuous layer of protoplasm. The narrow end of the cells forms a contractile process and runs along the tentacles and the body of the animals. The contractile processes form a distinct layer on the outer side of the lamella. The cells of the base are filled with granules secreted by the



Longitudinal Section of Hydra
1—Cnidoblast cell, 2—Mouth,
3—Tentacle, 4—Nematocyst,
5—Spermary, 6—Ovary,
7—Endoderm, 8—Coelenteron, 9—Bud,
10—Ectoderm.



Cnidoblast cell
1—Nematocyst,
2—Barb,
3—Wire.

protoplasm meant for the fixing of the animal upon weed or any other surface. Each cell has a large nucleus.

The second type of cell is the **interstitial** cell. These cells are round and fill up the intervening spaces of the narrow ends of the epithelio-muscular cells. These cells are kept in reserve and in necessity can give rise to the other cells of the body.

The third type is the **cnidoblast** cell found in the Ectoderm. These cnidoblast cells occur plentifully on the tentacles and are absent from the basal part of the animal. The cnidoblast cells project on the surface. They have a short process called **cnidocil** and a sac within called **nematocyst.** The narrow outer end of the sac is tacked in and produced into a long hollow thread which lies coiled up in the sac. The space between the thread and the sac is filled with fluid. The cnidocil is a sense organ. The wire when discharged paralyses the prey when any pressure is brought to bear on the outside of the sac, the thread has got three barbs at the base and comes away from the sac like an electric discharge.

The nematocysts are of three kinds :—

(*a*) Large kind with a straight thread provided with barbs at the base.

(*b*) Small kind with spiral thread.

(*c*) Small kind with straight thread and small sac.

The tentacles show some projections due to the presence of some cnidoblast cells both of the large and small variety. The large ones serve both for offence and defence. The sac pours out a fluid which has probably a corrosive action on the tough skin of the water-flea on which the Hydra lives. The main work of the nematocyst is to catch the prey and not to kill it until it is sent into the mouth. The cnidoblast cells arise from the interstitial cells. Firstly, these cells are found on the tentacular region and anterior region of the animal, but the cells move to other parts and take up their position when necessity arises. The germ cells arise from the interstitial cells. **Nerve cells** are found near the interstitial cells which are connected with the sense cells reaching the musculo-epithelial cells by fibres. There is no central nervous system. There is only a very rudimentary development of the nerve cells.

Endoderm :

The cells are columnar and tall. The cells contain granules which they secrete. There is a large vacuole containing the nucleus. The free ends of the cells have flagella. There are long narrow cells in the Endoderm which are granular in character and found towards the part near the mouth. They are known as Gland Cells. The secretion of these cells helps digestion. The numerous ordinary cells of the Endoderm are columnar and nutritive in function.

The green Hydrashows some round bodies in the Endoderm cells containing green colour. The green colour is due to Chlorophyll which is invariably present in plants. This is due to the association of a degenerate Alga with the Hydra. This sort of association of life is known as **symbiosis** as neither injures the other but they live a life of mutual help. The Alga is a minute microscopic plant related to Chlamydomonas and the group is known as Zoochlorella. The Zoochlorellae remove the waste products and CO_2 of Hydra and manufacture organic food with the help of chlorophyll. The Hydra takes away the excess of organic food and utilises it for its own nutrition.

Movements :

The movements are carried on by the muscular processes present in the outer portion of mesogloea though the basal cells can slowly move with the projecting pseudopods. The body of the Hydra contracts and it does not remain stationary even if the prey be absent. The body contracts and sends out the tentacles in a new direction. Sometimes the animals move, the tentacles attach to some new spot and the whole basal disc is removed with them. The movement is comparable to that of the looping caterpillar.

Nutrition :

The food of Hydra consists of small organisms and mainly water-fleas. When the animal has enough food it allows the prey to escape but if it is in a starved condition the touch of food makes the tentacles active. The prey is in contact with one of the tentacles and the other tentacles swing over it until it is sent into the mouth. While inside the enteron, digestive juices are secreted and the soft parts assimilated. The digestion might take place in the enteron *i.e.*, intercellular digestion or the flagella might send the food within the cells where the process is known as intracellular digestion. The undigested residue is eliminated through the mouth by the contraction of the wall. The Ectoderm cells do not take food directly but are nourished entirely by diffusion from the Endoderm cells. Thus the Ectoderm is protective and sensory while the Endoderm is nutritive.

Respiration and Excretion :

There is no special organ either for respiration or excretion. The two functions are carried out from the surface of Ectoderm and Endoderm cells.

Reproduction : Asexual and Sexual :

There are two kinds of reproduction in the Hydra, *viz.*, Asexual and Sexual. Asexual reproduction takes place by budding. A projection appears from the Ectoderm cells which is multicellular and forms a bud. This bud increases in size and gradually the tentacles appear. It may remain attached to the parent animal or may separate out to form a new individual.

Occasionally Hydra might reproduce by fission either longitudinally or transversely. The separated part grows out into a new Hydra. In fission growth is after separation but in budding growth takes place in the new individual while still attached to the original structure.

Regeneration :

Hydra has the power to build up its lost parts. provided it be not too small. The part must have the two layers with mesoglea. If a tentacle or part of the body is lost Hydra can regenerate the lost parts. The higher animals however do not possess this property except in the healing of wounds.

Sexual Reproduction :

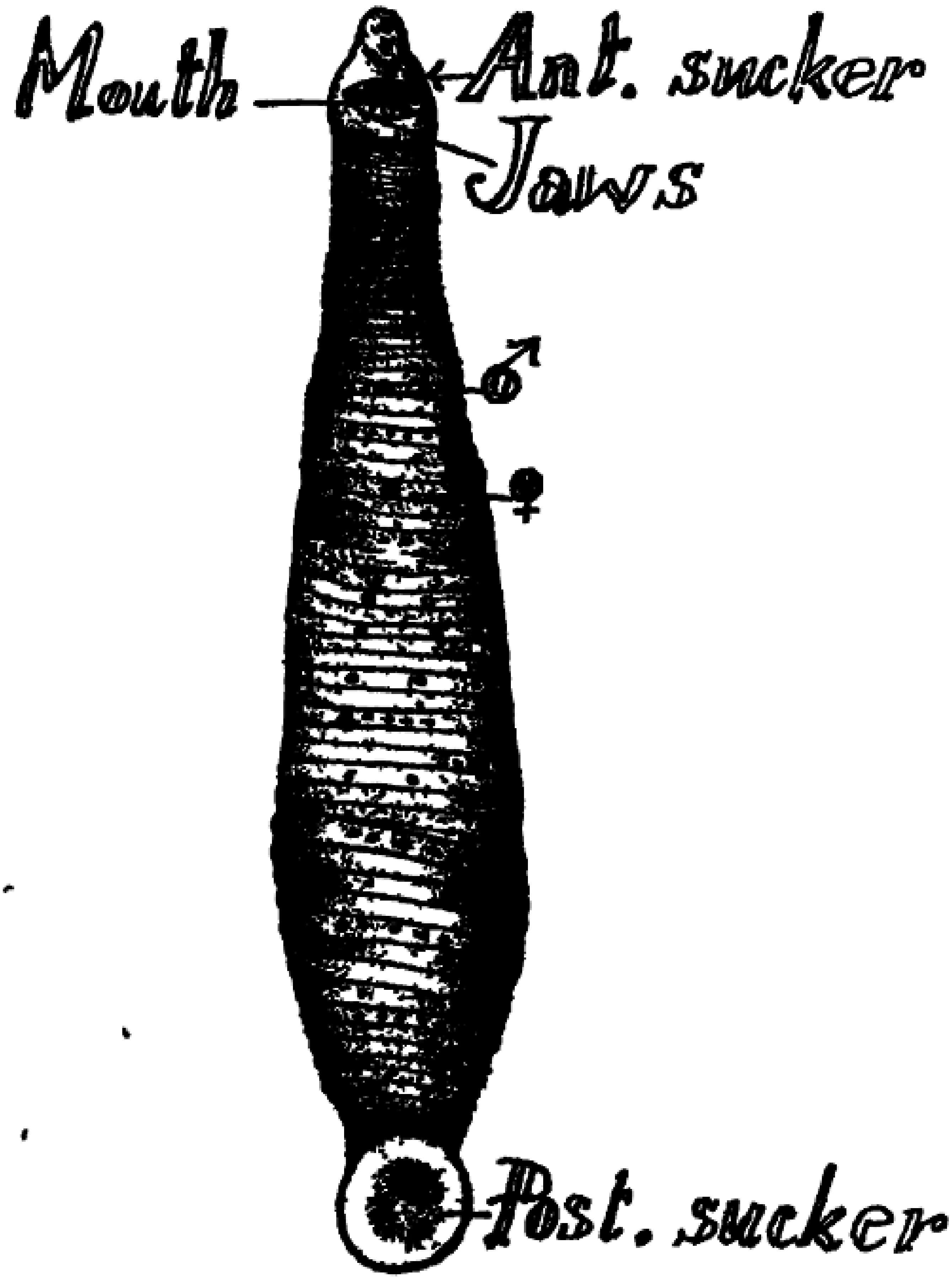
Sexual reproduction takes place in spring and summer. The animal is hermaphrodite *i.e.*, both ovary and spermary occur in the same animal. The sexual organs arise from the Ectoderm when the breeding season comes on. The testes are many in number and occur near the upper part while the ovary is single and found near the base. The organs are developed from the interstitial cells of the Ectoderm. In the case of the ovary the interstitial cells project and there is a covering of the musculoepithelial cells. There is developed an Oocyte which will develop into a single ovum and eat away all other interstitial cells. During fertilization the Ectoderm cells separate so as to expose the ovum and one sperm cell fertilises it.

In the case of the spermary, the interstitial cells develop into sperms each having a head and a tail and a covering of Ectoderm. When the sperms are ripe or mature the Ectoderm breaks down and the sperms float in the surrounding water. After fertilisation the ovum becomes oosperm or unicellullar embryo. Rapid division takes place of this cell which is known as segmentation. A mass of cells is formed called Morula or Polyplast which builds an outer shell. The animal comes out by the bursting of this shell. The Ectoderm and Endoderm are formed. The mouth develops and gradually the Enteron becomes functional and the tentacles appear as buds. Ultimately adopting the adult form and a fully developed Hydra is formed.

Leech :

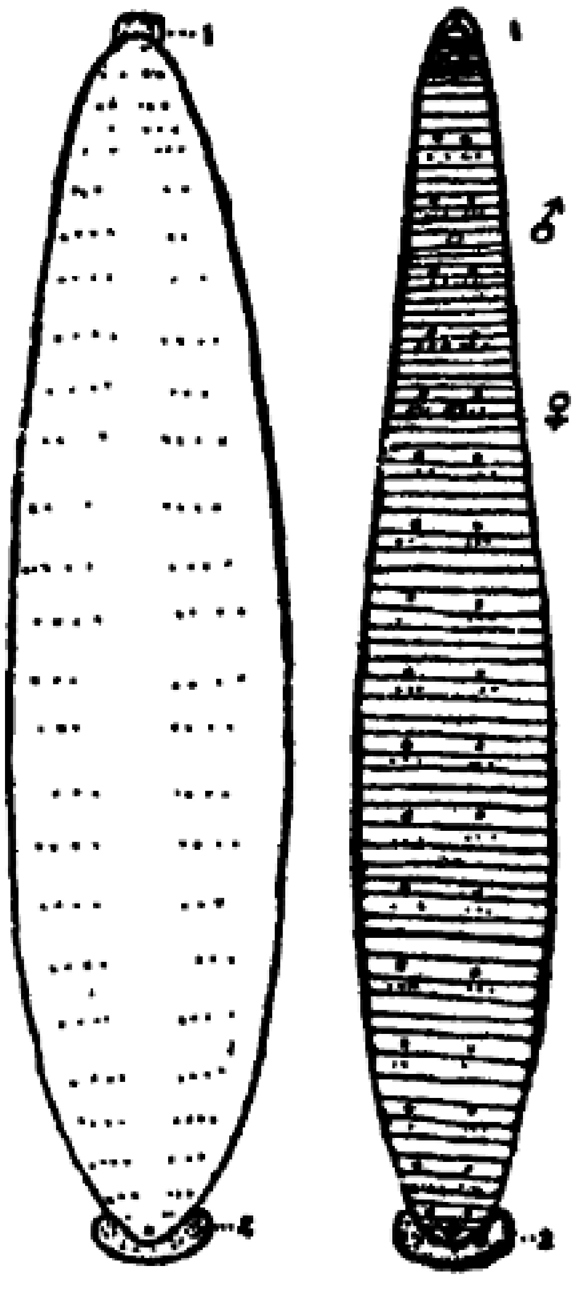
The scientific name of this group of animals is Hirudo, commonly known as Medicinal Leech because formerly it was largely used by medical men in their daily practice for the depletion of blood. The animal has got external markings corresponding to internal divisions. The animal is therefore called a segmented animal The phylum to which Leech belongs is known as Annelida

The Hydra has two layers in their body wall *e g* Ectoderm and Endoderm with a middle lamella Therefore it is known as Diploblastica. The Leech has there layers *e.g.* Ectoderm, Mesoderm and Endoderm. Therefore, it is called Triploblastica. All the higher animals



Leech.

are triploblastica. The Epidermis is formed from the Ectoderm whereas the great mass of tissues *e.g.* skeletal, muscular, excretory and generative organs are formed from the mesoderm. In Hydra the cavity is one but in higher animals two types of bodycavities occur in the mesoderm :—


Dorsal. Ventral.

1—Anterior Sucker.
2—Posterior Sucker.

1—Mouth with jaws.
2—Post. Sucker.

(1) The primary body-cavity or **haemocoele** or open blood vessels and,

(2) The Secondary body-cavity or true body-cavity or Coelome.

The functions of the coelome are (1) It forms a perivisceral cavity which surrounds the viscera and allows them to move.

(2) The walls give rise to the generative cells.

(3) It is sometimes concerned in Excretion.

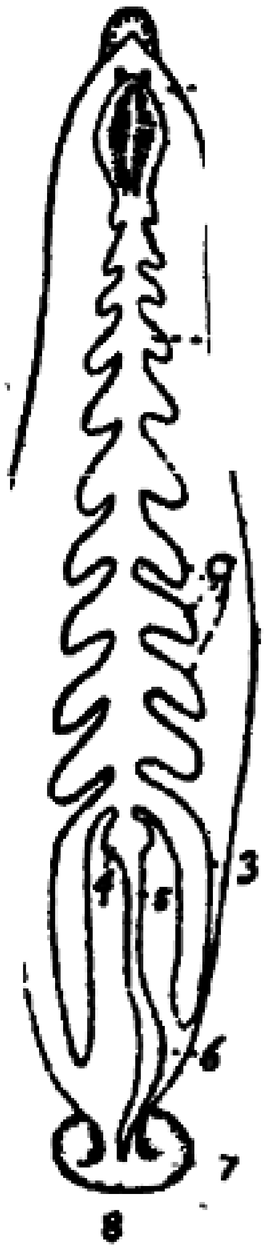
The haemocoele on the other hand is a system of spaces of more complex form than Coelome. Its function is to contain the blood and lymph. A blood vascular system is occasioned in the higher animals on account of the great mass of internal tissue.

The Leech is generally found in the fresh water ponds, ditches, slow running streams and marshy places. Formerly it was bred in special ponds in England for the use of the medical practitioners. Normally it lives by sucking the blood of toads, frogs and fishes but in the adult stage it can also live on warm-blooded animals and even on man. To induce the animal to suck the blood of man the skin may be moistened with milk or blood. A small cut acts admirably for the purpose. A Leech can draw 1 to 2 drams of blood only. The length of the animals varies from one to five inches. Each end of the animal is provided with a downward facing sucker. The body of the animal is segmented and recently it has been shown that the segments are always 33 in number. Some of the segments are fused together as for example, the posterior sucker consists of 6 or 7 segments. Each segment is generally divided into 5 annular rings. The mouth is situated in the Anterior sucker while the Anus opens by a small aperture at the base of the posterior sucker. The male and the female organs open by median apertures on the 10th and 11th segments respectively. The Excretory systen is in the form of a pair of Nephridia occurring in each segment from the 6th to the 22nd segment. Sensory Papillae occur in the form of a ring in each segment on the first annulus. On the head these papillae form a pair of eyes in each segment. The animal moves by looping movement and swims by the undulations of the body. The animal is covered by a thin cuticle which is shed from time to time. Below the cuticle is the Epidermis. The bloodvessels form capillaries below the Epidermis. The skin in the Leech serves as a respiratory organ because the bloodvessels come in contact with the surrounding water through the skin. Below this, muscle layers run in circular and longitudinal fibres, within which a special tissue occurs called the Botryoidal tissue. The walls of the Boytryidal tissue are full of black pigment and the cavities are full of blood. This tissue functions as a perivisceral cavity and imbeds the alimentary tube.

The Alimentary Canal :

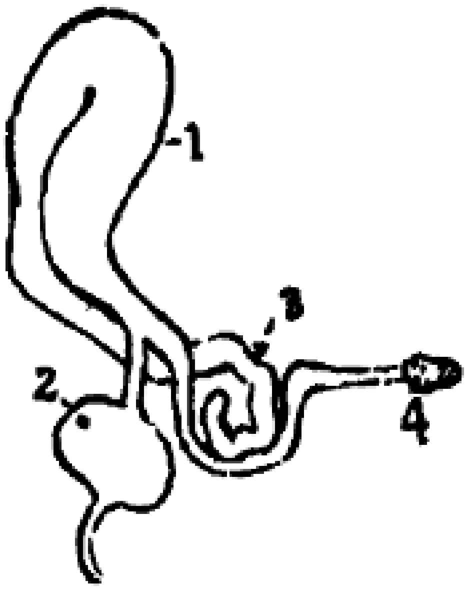
The mouth has three jaws covered by cuticle. This is used in inflicting the characteristic triradiate wound on the prey. The mouth is followed by the muscular pharynx which has unicellular glands. The glands by their secretion prevent the blood from clotting. The blood is sucked and sent to the crop for storage. This secretion often leads to the continued bleeding in animals where a leech was attached. In Physiological experiments extracts of the head of Leeches are used to prevent clotting of blood. The pharynx is followed by a short Œsophagus and then comes the crop. The crop has eleven pairs of cœca which are dilated through the accumulation of blood. The last pair of cœca is the largest and extends its limbs right up to the anus. The crop leads into a small globular stomach is followed by a short intestine and the ultimate part is the dilated rectum opening by an aperture called Anus. The blood when digested inside the stomach turns green.

Alimentary tube.



1—Pharynx, 2—Crop,
3—Large caecum, 4—Stomach,
5—Intestine, 6—Rectum,
7—Anus, 8—Post Sucker,
9—Caeca.

Nephridium.



1—Duct,
2—Bladder,
3—Duct,
4—Lobe of nephridium.

It is said that a full meal may last from six months to a year.

Excretory system :

The excretory organs are the 17 pairs of Nephridia. The nephridia are V-shaped rods of cells. The glandular tissue is traversed by a system of intracellular ductules. There is no internal opening but in the testes segments. the nephridia have a swollen end in the capsule of the testis.

Blood Vascular system :

There are two systems of tubes containing a fluid like blood—a red plasma with a few colourless corpuscles. One system is the true blood vascular system consisting of two lateral trunks which are joined before and behind and in the middle by capillaries. The lateral vessels can contract but there are no hearts.

The other system consisting of a dorsal and a ventral longitudinal *sinus*. The walls of this system are thinner than those of the other system. The second system represents the cœlome because it communicates with the capsules of the ovary and testis. The botryoidal tubes communicate with the sinuses.

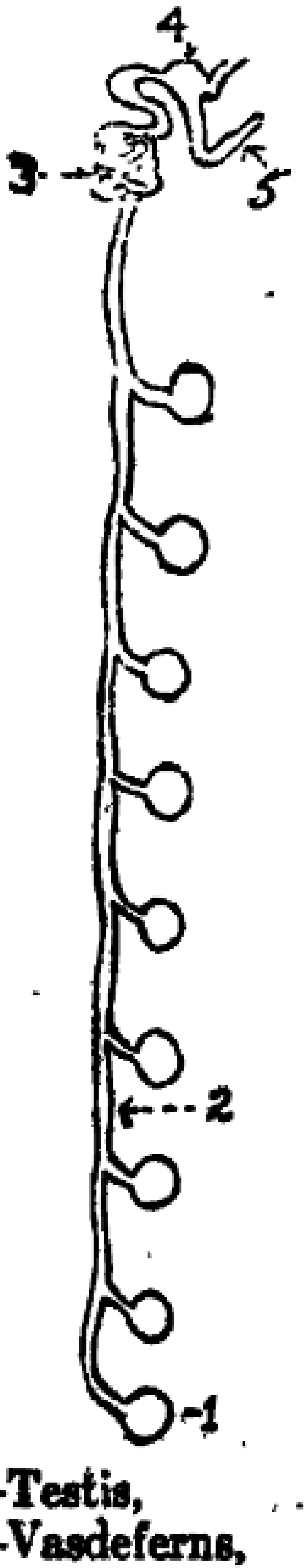
Nervous system :

The nervous system consists of two cerebral "ganglia" at the head part above the pharynx. There are two circumpharyngeal commissures connected with a double ventral nerve chord. The ventral chord carries about twenty-three pairs of ganglia, almost one for each segment. The subpharyngeal and the last ganglia represent several fused ones. Nerves pass to the body from the cerebral and other ganglia.

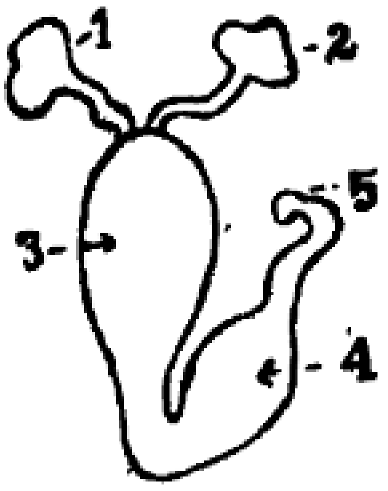
Reproductive system :

The animals are hermaphrodite. The testes are ~~nine~~ eleven pairs of organs from 12th to ~~20th~~ 22nd segments. The testes of each side have a common passage called "Vas deferens." The two Vasa deferentia join to form a coiled structure called Epididymis in the 10th segment

Male.



1—Testis,
2—Vasdeferns,
3—Epididymis,
4—Sperm sac,
5—Penis.



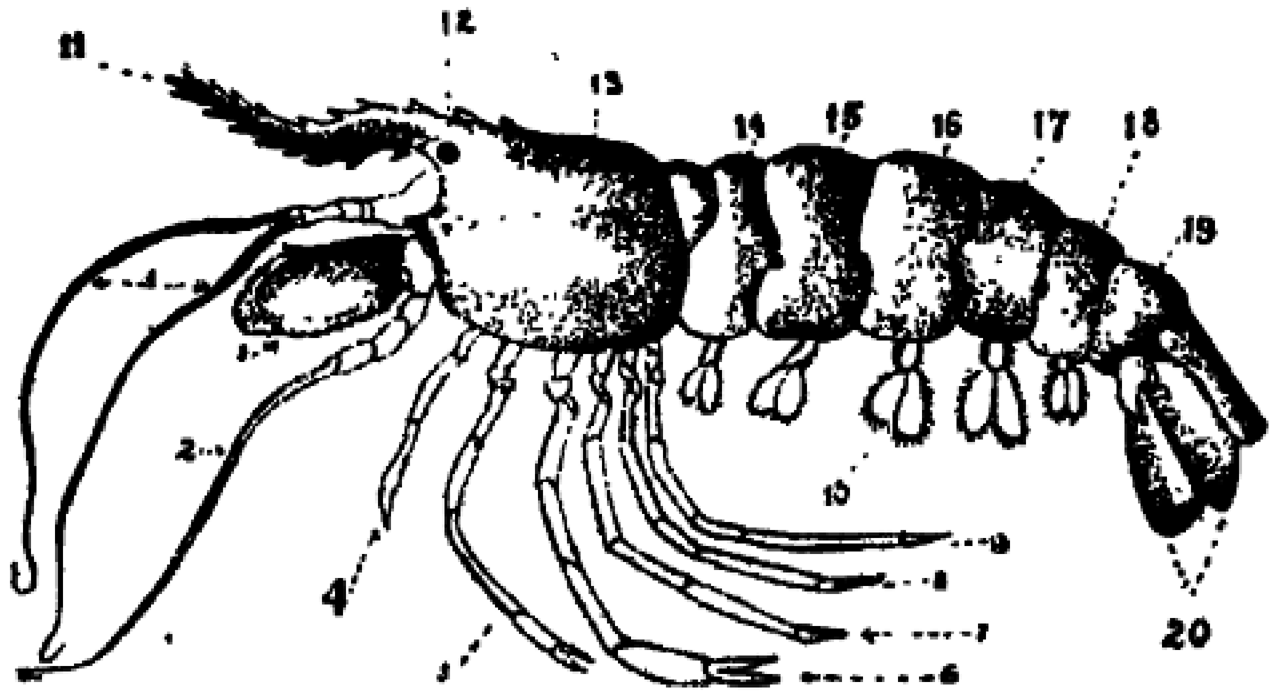
1—Ovary,
2—Ovary,
3—Oviduct,
4—Vagina,
5—Opening.

and open by a muscular "penis." The "Penis" has a "Prostate" gland at the base.

There occur a single pair of ovaries which have oviducts uniting into a median vagina, and opening by the single aperture in the 11th segment. The Eggs are laid in cocoons secreted by the clitellar glands in the skin of the 10th to 12th segments. The eggs are laid on the holes of the banks; the young resembles the parents and at first feeds on the juice of small water-insects. It takes about three years for the maturation of a young leech. Thus the group of leeches is characterised by :—

(1) Segmentation of the body.

Prawn



1—1st antenna, 2—2nd antenna, 3—exopodite, 4—3rd maxilliped. 5—1st Walking leg, 6—2nd Walk-leg, 7—3rd Walk-leg, 8—4th Walk-leg, 9—5th Walk-leg, 10—Swimmeret, 20—Last pair of Swimmerets with telson on the back, 11—Rostrum, 12—Eye, 13—Cephalothorax. 14 to 19—Abdominal Segments.

(2) Closed blood-vascular system.

(3) Nervous system with cerebral-ganglia and a double ventral nerve-chord.

(4) Presence of cœlome.

(5) Paired Nephridia.
(6) Hermaphrodite condition.

The freshwater prawn (palaemon) :

The Prawn belongs to the phylum Arthropoda. The word Arthopoda is derived from " Arthron " meaning joint and podos a foot. The animal has jointed feet. The prawn, the scorpion and the insects, Butterfly, Bees, Ants etc., all belong to this phylum, because they all possess jointed feet. This is the largest phylum in the whole animal kingdom and is comparable in number to all the animals put together of other phyla. The Prawn occurs both in fresh and saltwater. The popular Bengali name of the animal is " Goldachingree," and the scientific name is Palæmon. The Bengal variety is mostly confined to freshwater ponds, canals and rivers. The other variety of " Chingree ' known as " Bagda chingree " is found only in saltwater Jheels and is known scientifically as Penæus. The food of Palæmon consists of algæ, moss and other weeds.

The Arthropoda is divided into four classes and the name of the class to which the prawn belongs is called Crustacea.

The Prawn belongs to the order **Decapada** which owes its name to the fact that its members have their hinder five pairs of thoracic linbs adapted for locomotion typically as walking legs. The order includes the most highly organised crustaceans, such as prawns & shrimps, and the true crabs.

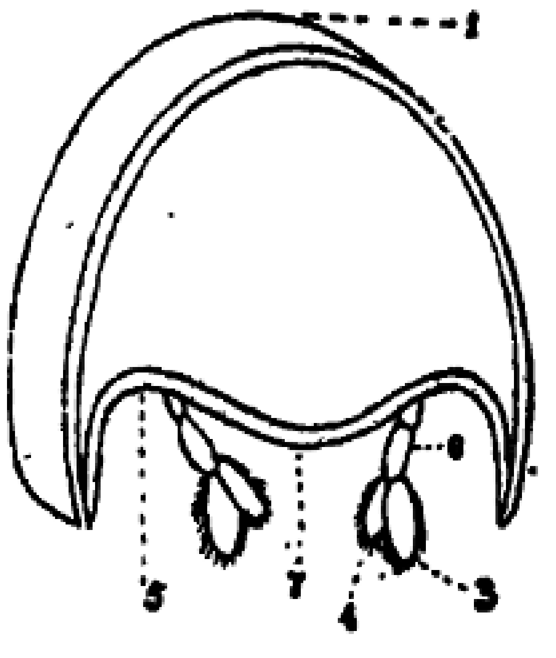
The systematic position of Palæmon is shown in the following scheme :

Phylum : Arthropoda, class : Crustacea, order : Decapoda. Sub-order : Natantia. Family : Palæmonidæ Sub-family : Palaemoninae, Genus : Plæmon.

External features : prawn :

The body is bilaterally symmetrical. It is segmented like that of the Leech but the number of segments is much less being only 19 in all, some of the segments being fused in front. The whole body is covered by a hard chitinous cuticle. The body is divisible into a fused anterior portion called the **Cephalothorax** and a segmented posterior portion called the **Abdomen.** The body is provided with variously modified appendages *e.g.*, legs, jaws etc. covered by jointed exoskeleton, the movable segments are known as podomeres. The Cephalothorax has a shield-like covering called the **Carapace.** The Carapace bears a saw-like structure,

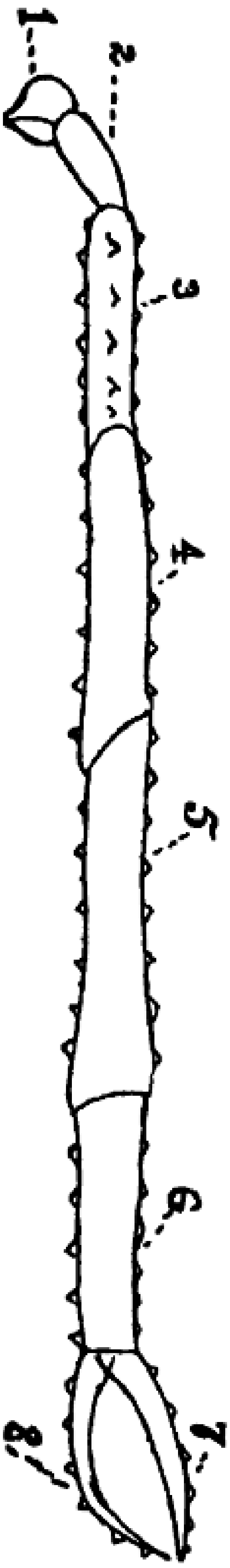
Transverse Section of abdomen of Prawn.



1—Tergum, 2—Pleuron, 3—Exopodite, 4—Endopodite, 5—Epimeron, 6—Biramous appendage, 7—Sternum.

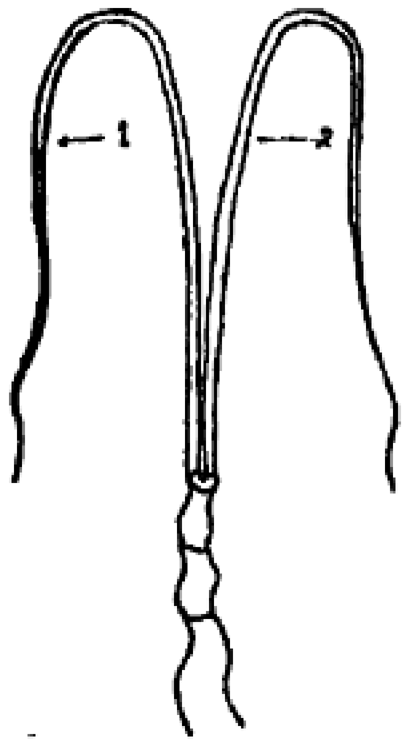
called the **Rostrum.** The Cephalothorax is formed by the fusion of a number of segments. The presence of several pairs of appendages testify to this fact. A flat piece called **Telson** is found at the end of the abdomen on the undersurface of which the anus opens. The Telson bears no appendages. Each abdominal segment has a dorsal piece at the back called **Tergum** and a narrow piece in the belly part underneath called the **Sternum** with a pair of V-shaped prolongations called **Pleura** joining them at the sides. A continuous ring is formed by the tergum, sternum and pleura of each segment. The limbs are joined to the sternum and the portion between the limb and the pleuron is called **Epimeron.** The terga overlap one another and the tergum of each segment is joined to the next by thin cuticle which allows some movement of the animal. The dorsal plate and carapace are fused to form dorsal shield. There is a chamber in which the gills lie on each side. This chamber is called the Gill-chamber and the covering is known as Gill cover or **Branchiostegite.** The mouth and the sense organs lie in the head region. The mouth lies a little below the front end. Below the rostrum there are two stalked eyes, one on each side and below the eyes are seen two pairs of Antennæ one pair on each side. These antennæ serve as sense organs.

The genus Palæmon has carapace less than one-third of the length of the animal: rostrum long and armed above and below with a varying number of teeth. The first pair of legs small, slender and chelate; the second pair of legs also chelate, much larger than the former, the remaining pairs simple and clawed. The third maxilliped pediform: The gills contisting of three epipodites, one podobranch, two arthrobranchs and five pleurobranchs.



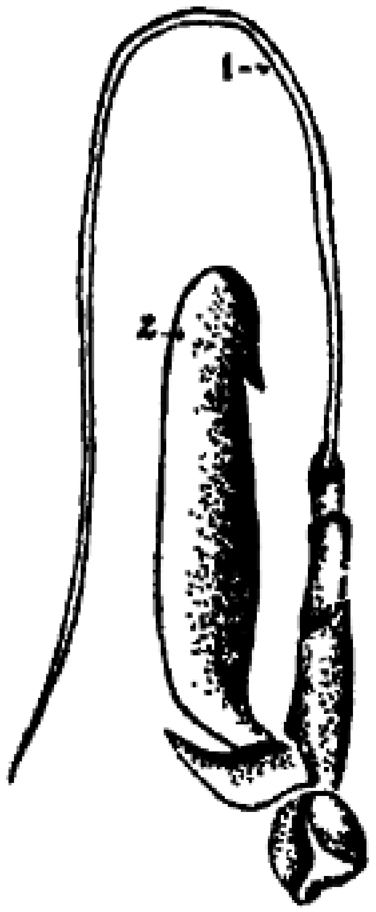
1—Coxopodite, 2—Basipodite, 3—Endopodite & Ischiopodite, 4—Meropodite, 5—Carpopodite, 6—Propodite, 7—Dactylopodite, 8—Chela.

1st Antenna of Prawn.



1 & 2—Flagella.

2nd Antenna of Prawn.

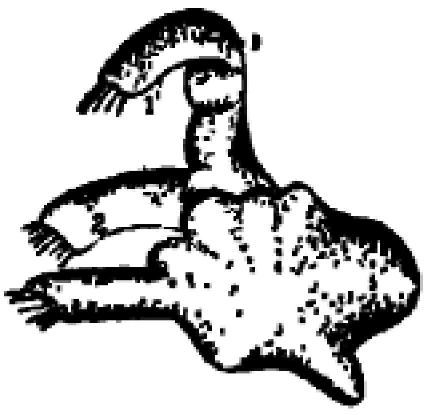


1—Flagellum, 2—Exopodite.

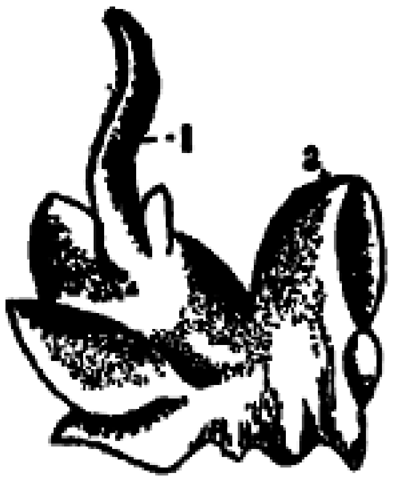
Appendages or limbs of prawn :

There are thirteen pairs of appendages in the Cephalothorax but some authors calculate the number as fourteen counting the stalked eyes as one pair. The abdominal part has six pairs of appendages. The hardened pieces of the exoskeleton are called the sclerites and the thin membrane connecting them at each junction is called arthrodial membrane. The appendages are of **biramous** type *i.e.*, more or less the ultimate portion is divisible into an Exopodite and an Endopodite at least in the larval condition. The total number of appendages is therefore nineteen excluding the stalked eyes and the telson which is not a segment. The first five segments form the head, the next eight thorax and the last six with telson abdomen. The third pair of Maxilliped show all the parts of a complete limb. Each has a basal part called Coxopodite above it, is the basipodite. The Coxopodite and the Basipodite together form the Protopodite. The Coxopodite bears on its outside a flat portion called the Epipodite bearing a fringed structure called the Gill. The base of the Epipodite bears a tufted knob called the Coxopoditic Setæ or Setobranch. The Basipodite bears a slender jointed structure on the outside called Exopodite and a stout five-jointed inner structure called Endopodite. The joints are named from the Basipodite as Ischiopodite, Meropodite, Carpopodite, Propodite, and Dactylopodite. The third maxilliped resembles a leg. The limbs are made on this plan but some part may be absent on account of the particular function it has to perform. The first two pairs of limbs are sensory which are used in search of food. The food consists of either living or dead organic matter. The next six pairs are used as jaws and are found close to the mouth because they have to bring food to the mouth and also help in chewing. The five pairs of walking legs are used exclusively for walking. The first two pairs end in pincers or Chelæ and are called Chelipeds which are used for grasping or catching the prey. The third and fifth legs bear the openings of the Reproductive organs at their bases. The appendages of the Abdomen are six pairs of short legs used for swimming and hence are known as swimmerets. The Telson is used for making rapid backward strokes.

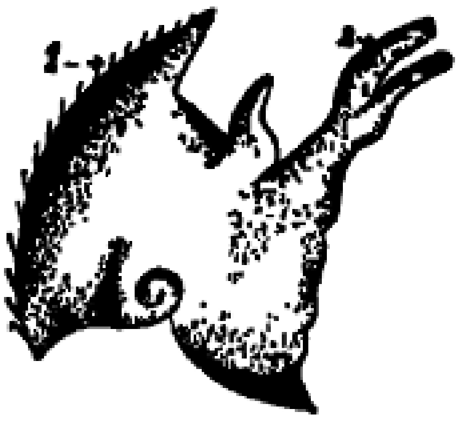
The first pair of appendages are known as **Antennules.** Here the protopodite is three jointed instead of two. The first joint bears on its upper side a slit edged with bristles, the **Statocyst.** The third joint bears two many—jointed flagellae or feelers. They are often compared to exopodite and Endopodite. The outer flagellum bears on its under side of joints pecuilar bristles which are supposed to serve the sense of smell. The second pair of **antennae** bears the opening of the green gland or the Excretory organ at the base of the Coxopodite. The Basipodite is divided into two pieces. The Exopodite is a flat, triangular pointed scale while the Endopodite is a long flagellum. The third appendage is the pair of **mandibles.** The Coxopodite is a strong plate with toothed incisor edge which bites against the fellow on the other side of the body. Above the incisor edge and so hidden from ventral view is a broad irregular ridge called the molar process. In front of the Coxopodite, a three-jointed palp is formed by the Basipodite and an Endopodite. The mouth bears the two mandibles at the two sides. The fourth pair of appendages are the first pair of maxillae or maxillulae. Each has three thin plates jointed to the basal piece. One plate is an expansion of the Coxopodite the second represents the basipodite and the third the Endopodite. The fifth limb



1st Maxilla.
1 & 2—Protopodite.

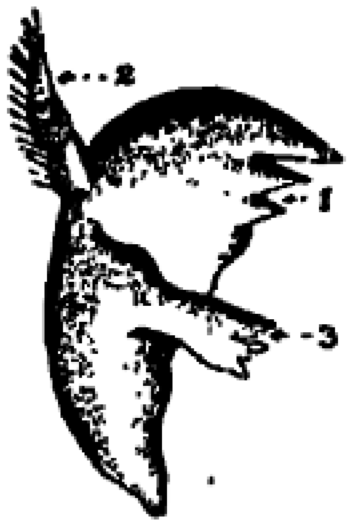


1st Maxilliped.
1—Exopodite,
2—Protopodite.

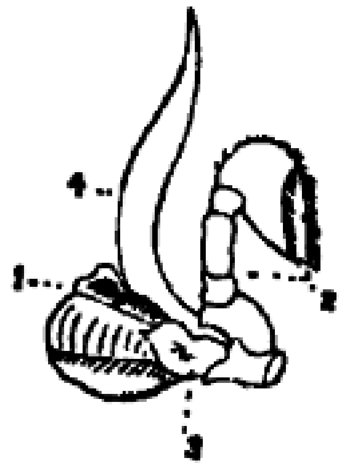


2nd Maxilla.
1—Scaphognathite,
2—Protopodite.

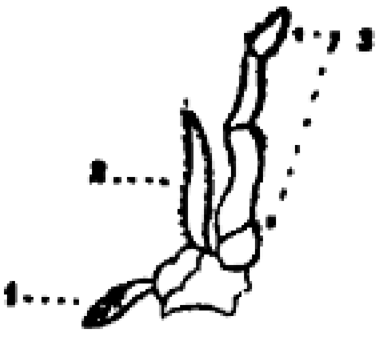
Mandible of Prawn.



1—Teeth,
2—Endopodite,
3—Protopodite.



2nd Maxilliped,
1—Podobranch,
2—Endopodite.
3—Protopodite.
4—Exopodite.

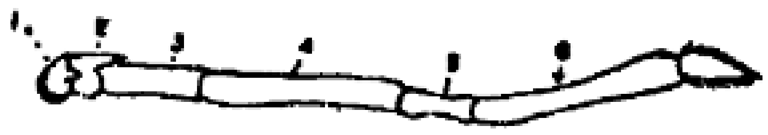


3rd Maxilliped,
3—Endopodite.
2—Exopodite.
1—Gill,

is the second pair of maxillae. It is deeply cut into several parts. The protopodite bears two thin lobes directed towards the middle line of the body and each in turn is divided into two. The Endopodite is a narrow structure directed forwards. The Exopodite is a wide plate directed forwards from the outer side of the limb and is known as **Scaphognathite.** The second Maxilla is situated in the front end of the Branchiostegite. The function of the Scaphognathite is to drive the current of water over the gills and thus bathing the gills and driving the current forwards out of the Gill chamber. It serves as an accessory organ of respiration.

The sixth limb or the first pair of Maxillipeds belong to the thorax. It has two broad basal lobes called Coxopodite and basipodite, the Endopodite is small and unjointed and Exopodite is large and looks like the third Maxilliped. The Epipodite is present but does not bear the gill. The second pair of Maxilliped is almost like the third but the Endopodite is small and the Exopodite is relatively large. It bears a gill. The third has been already described. Then comes the five pairs of walking legs or Pereipoda.

Fifth leg.



1—Coxopodite,
2—Basi,
3—Ischio,
4—Mero,
5—Carpo,
6—Pro,
7—Dactylopodites.

The first two pairs bear pincers and are called Chelipeds. Each of the legs shows a five jointed Endopodite and the exopodite is wanting. The four pairs of legs bear gills on the Epipodite but the fifth pair do not bear any gill. The leg has the following parts from the base :—

(1) Coxopodite, (2) Basipodite, (3) Ischiopodite, (4) Meropodite, (5) Carpopodite, (6) Propodite and (7) Dactylopodite.

The opening of the female reproductive organ is at the base of the 3rd leg through which the eggs are laid. There is a similar opening at the base of the 5th pair of legs through which the sperms are shed from the male generative organ.

The abdominal appendages are the **pleopods** or **swimmerets.** Each has a short Coxopodite, a long Basipodite and an Endopodite and Exopodite, each having imperfectly separated joints. The Endopodite is larger than the Exopodite and both bear bristles. In the male the first joint of the Endopodite bears a rolled up scroll. The sixth abdominal pair of appendages are very large. The protopodite is short and the exopodites and endopodites are very broad. They form with the telson the tailfin used for hasty jerks in swimming. The base of each leg is attached to the body by arthrodial membrane.

Outer Epidermis and Cuticle of Prawn :

The Epidermis of prawn is a layer of protoplasm with many nuclei but columnar Epithelium generally occurs with syncytium or undifferentiated at places. The Epidermis secretes a cuticle on the outside which becomes hard due to the deposit of lime salts and remains thin at the joints to allow movements of the body. The hard cuticle forms the Exoskeleton of the body. The animal sheds off the cuticle from time to time and a new one is secreted. This is called Moulting or Ecdysis of Prawn. The basis of cuticle is chitin which is a compound of ammonia. The animal gets rid of nitrogenous waste material through this cuticle. When the animal is leaving the old cuticle a split appears on the back and along the limbs and the animal escapes from this old cuticle. In the meantime the animal has to hide itself because the new cuticle takes several days to harden. The male generally moults twice a year and the female once a year.

Skeletal and Muscular System :

The animal has an outer skeleton of thick and hard cuticle. The thorax portion has an internal skeleton in the form of hard ingrowths of cuticle. This is called Endophragmal skeleton.

The movement of the body is carried on by various striped muscle fibres. There is no continuous muscular layer. There are two sets of muscles for the movement of the abdomen. One is the extensor system beginning from below the carapace and continued along the base of the terga. The contraction of these muscles straighten the abdomen. There is another set of more powerful muscles on the ventral side attached to the sterna and Endophragmal skeleton. These by their contraction bring together the sterna and thus contract the abdomen. By these muscular movements jerks are produced and the animal escapes from its enemies. Its gentle movements are carried out by the walking legs and the padding of the abdominal swimmerets.

Appendages and Segments of Prawn.

Head	1.	First pair of antennules	Sensory limbs.
	2.	Second „ „ antennæ	
	3.	Mandibles	
	4.	First pair of Maxillae	
	5.	Second „ „ „	
Thorax	6.	First pair of Maxillipeds	Jaws.
	7.	Second „ „ „	
	8.	Third „ „ „	
	9.	First pair of legs	Legs.
	10.	Second „ „ „	
	11.	Third „ „ „ — (Female)	
	12.	Fourth „ „ „	
	13.	Fifth „ „ „ — (Male)	
Abdomen	14.	Abdominal limb	Swimmerets.
	15.	„ „	
	16.	„ „	
	17.	„ „	
	18.	„ „	
	19.	Telson & „ Tail fin.	

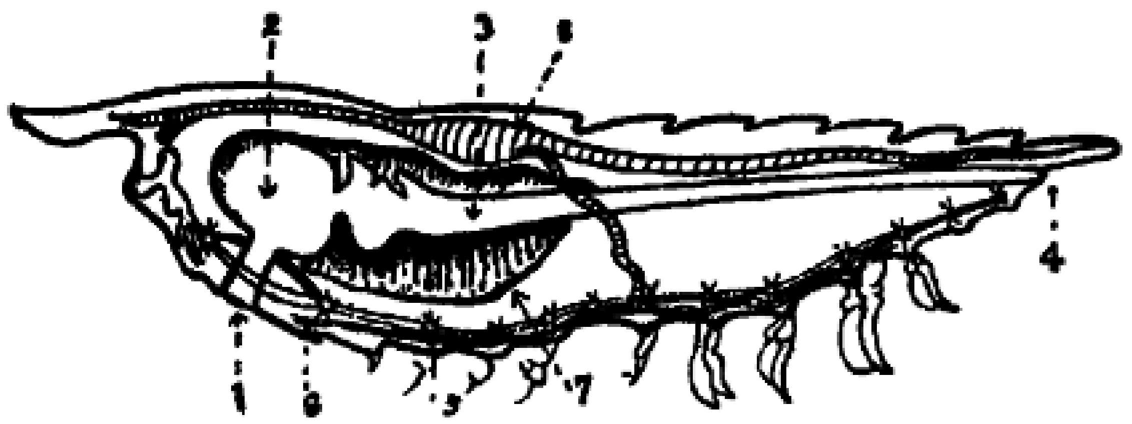
Body cavity :

The body cavity or the perivisceral cavity of prawn is large and the organs lie in it. This is **haemocoele** because the blood vascular system comes in contact with this cavity. It is not a cœlome.

Alimentary system :

The alimentary canal is derived from three regions in the embryo, the stomodaeum, the mesenteron and the proctodaeum. The stomodaeum develops into the foregut consisting of the buccal cavity, the oesophagus and the stomach ; the mesenteron forms the adult midgut and the hepato-pancreas while the proctodaeum develops into the hindgut. The foregut and the hindgut have an internal lining of cuticle continuous with the cuticular covering of the integument but the long midgut has a soft endodermal lining.

The mouth is a wide aperture situated on the ventral side of the Cephalothorax. It is bounded in front by a wide upper lip or Labrum and behind by a pair of lower lips or Metastoma. There is a short œsophagus or gullet which leads into the stomach or Proventriculus. This stomach has two chambers, a large front part or Mill chamber often called the "Cardiac division" of the stomach, and a smaller hind part or "Filter chamber," often called "Pyloric division" of the stomach, separated from the mill chamber by a pit in the roof. (Two large plates are found in the two divisions of the stomach and are known as Cardiac and Pyloric Ossicles. Embedded in the floor of the cardiac stomach lies a large triangular cuticular plate called the **hastate plate** on account of its resemblance to the head of a spear. They are joined in the middle by two smaller pieces called Urocardiac and Prepyloric ossicles. The forked middle tooth projects from the prepyloric ossicle. At each side of the pit the cardiac and pyloric ossicles are connected by two more pieces the Zygocardiac ossicle and the Pterocardiac ossicle. The cardiac stomach is generally found filled with semi-solid food. In a living prawn the expansion and contraction of the stomach, allows the food to mix up with the hepatopancreatic secretion and thus the food is digested. There is no gastric mill in cardiac stomach. The filter chamber leads into the short midgut or Mesenteron. The mid-gut is followed by the almost straight hindgut or intestine. The filter-chamber has many ridges covered with bristles which serve to strain out the particles of food so that only fine food enters the midgut. On each side of the midgut the Liver or Hepatopancreas opens. The Hepatopancreas is a large lobed yellow gland consisting of numerous short tubes which open by ducts on each side of the digestive gland. The food is either raked up by the third maxilliped or torn to pieces by the Chelipeds and then passed into the mouth by the jaws. The mandibles cut the food into small pieces and then send to the proventriculus. Then the food passes to the midgut where with the digestive fluid from the gland disgestion and absorption take place. The filtrate from the food passes backwards into the hepatopancreatic ducts, while the refuse over the filter consisting of larger particles of undigested or indegestible food is pushed upwards into the dorsal chamber of the pyloric stomach, whence it is pressed backwards into the midgut. The hindgut has a swelling near about the anus. The hepatopancreas or the so-called liver is a massive compact organ, orange-red in colour consisting of two lobes. The large bulk lies behind the cardiac stomach but a part of it lies around the floor and sides of the stomach. Dorsally it is covered by reproductive organs and heart. The intestine leads to the anus which opens below the telson,

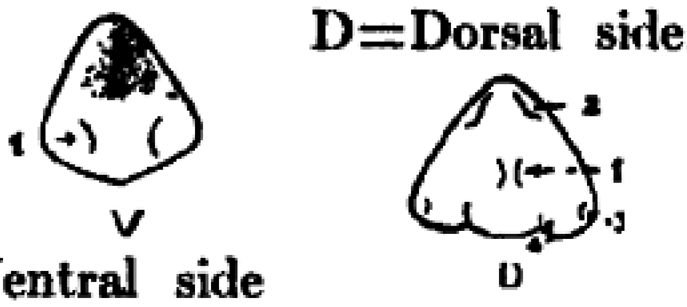


L. S. of prawn

1—Mouth, 2—Stomach, 3—Intestine,
4—Anus, 5—Nerve cord, 6—Ventral vessel,
7—Digestive gland, 8—Heart.

Vascular system :

The Heart is a triangular (on surface-view) hollow organ on the dorsal side of the animal with muscular walls. It is situated in the thorax within a space called Pericardial Sinus. Five pairs of openings called Ostia are found on the heart through which the cavity of the Heart communicates with the pericardium. The ostia are guarded by valves, which allow the blood to enter the Heart from the pericardial sac but not otherwise. The Ostia are situated in the following way :—



Heart

D=Dorsal side.

Ventral side

1=Ostia

(1) One pair is seen on the ventral side of the heart.

(2) Second pair is found on the outer sides of the dorsal surface.

(3) Third pair occurs dorsally close to each other in the middle line.

(4) Fourth pair is seen dorsally at the posterior border of the heart.

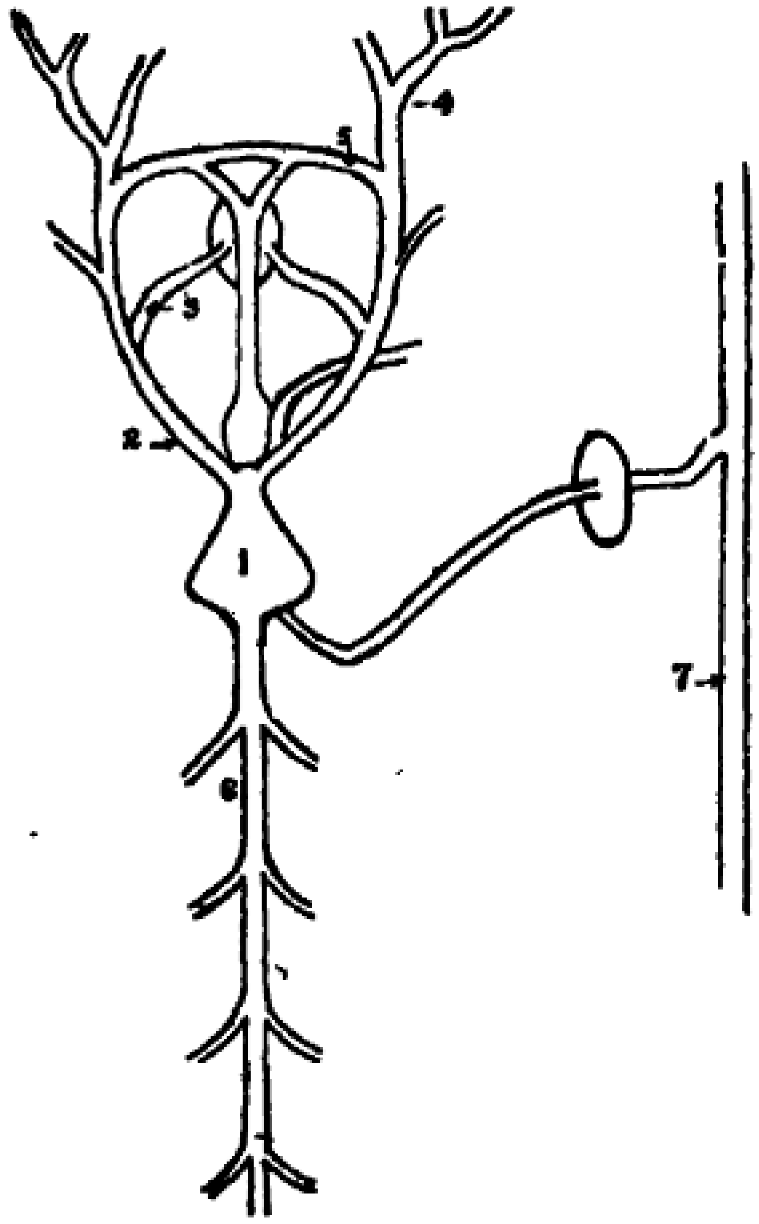
(5) Fifth pair is at the outer angles of the posterior border.

Arteries and veins :

Blood vessels which are sent from the heart to different parts of the body are called Arteries. They carry pure oxygenated blood to the different parts of the body. Blood vessels which bring blood from various parts of the body to the Heart are called Veins. They carry impure blood.

Blood vessels of prawn :

The heart receives all its blood from the pericardial sinus. When the heart contracts, it pumps out all its blood into the arteries which have strong muscular walls.

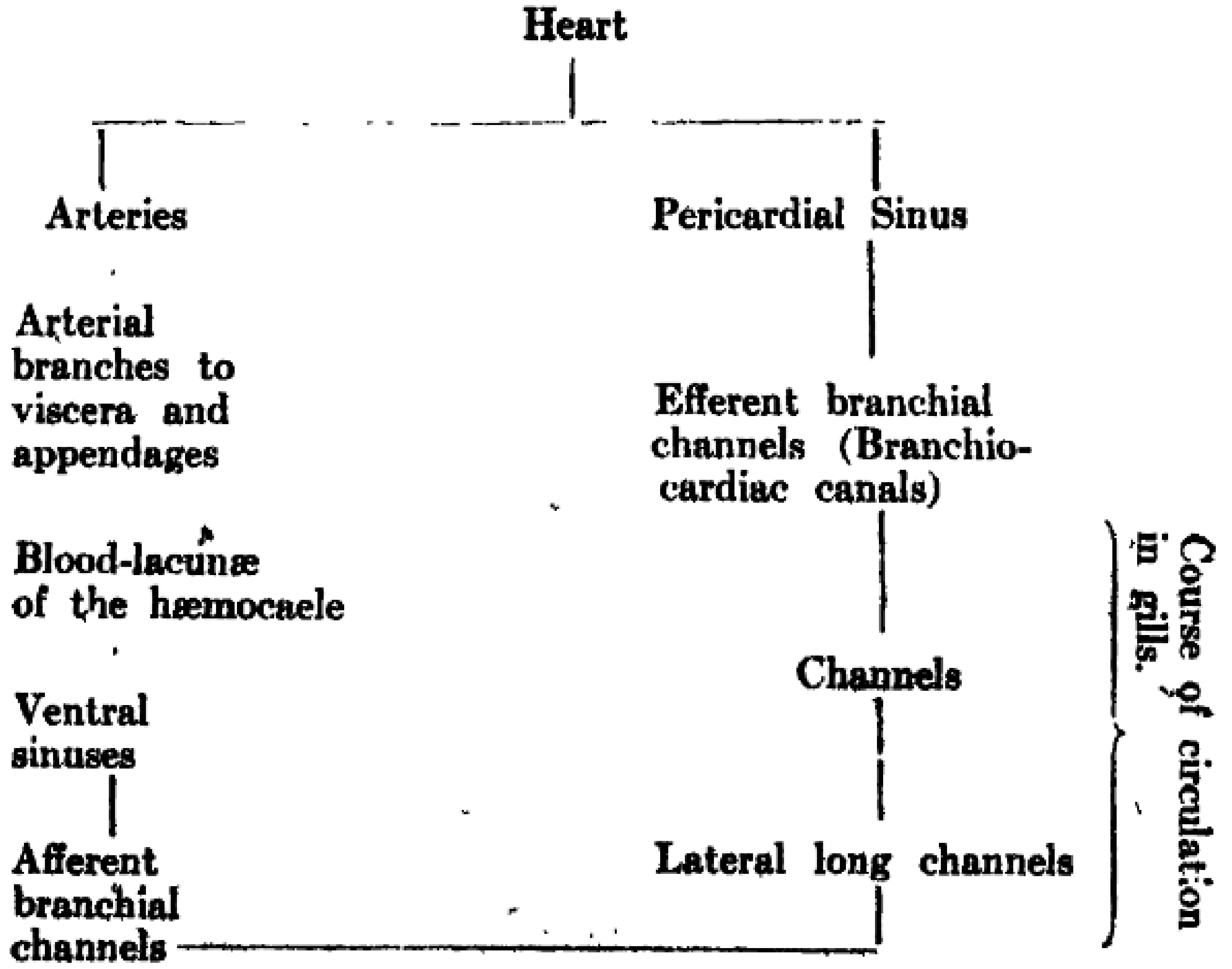


1—Heart, 2—Antennary, 3—Hepatic,
4—Antennary, 5—Anastomosis,
6—Dorsal Abdominal, 7—Ventral Abdominal.

Three blood vessels arise from the front end of the Heart—a median Ophthalmic artery which runs forwards over the stomach and joins the antennary arteries. Two antennary arteries run forwards on the two sides of the opthalmic artery. Each antennary artery divides into three branches, (1) a pericardial branch; (2) gastric branch and (3) a mandibular branch supplying blood to the pericardial sinus, the cardiac stomach and the mandilular muscles respectively. After giving off these branches, each antennary artery divides into a dorsal and a ventral branch. The dorsal branch gives an optic artery to the eye and the ventral branch supplies the antennule and the antenna. Below the antennary arteries are given off two Hepatic arteries which supply the Liver. The hinder portion of the Heart gives off a vessel which at once divides into a (1) Supraintestinal artery which runs below and is situated above the intestine and supplies the muscles of the intestine and (2) a sternal artery which goes through an opening in the ventral nerve cord in the ventral part and divides into a Ventral Abdominal and a Ventral Thoracic artery by which the limbs are supplied. The blood vessels branch minutely but there are no capillaries. Ultimately the branches open into Sinuses and thus the Blood vascular system comes in direct contact with the body cavity, for which it is known as Hæmocoele. The largest of these is the Perivisceral Cavity. The blood from the limbs and to a great extent from the perivisceral cavity collects in a sternal sinus which lies in a space formed by the Endophragmal skeleton which contains the ventral Nerve cord and the Ventral blood vessel. The blood is carried from this sinus by afferent branchial sinuses for oxygenation in the Gills. After oxygenation pure blood passes by Efferent branchial sinuses to the pericardial sinus from which it enters the heart and becomes distributed by various vessels. Part of the blood around the stomach passes by a vessel from the branchio-stegite to the pericardial sinus. The vascular system of the Prawn is said to be open.

The blood of Prawn is a clear fluid which contains white corpuscles and coagulates readily which is an advantage for an animal having open vascular system. Hæmocyanin an organic compound of copper plays the same part as Hæmoglobin of higher animals. It takes up the oxygen in the respiratory organs and gives it off to the tissues. In the oxidised condition it tinges the blood blue but colourless when deoxidised.

The course of circulation of blood in palaemon.


Heart
Arteries
Pericardial Sinus
Arterial branches to viscera and appendages
Efferent branchial channels (Branchio-cardiac canals)
Blood-lacunæ of the hæmocaele
Channels
Course of circulation in gills.
Ventral sinuses
Afferent branchial channels
Lateral long channels

The blood-sinuses and the blood-channels :

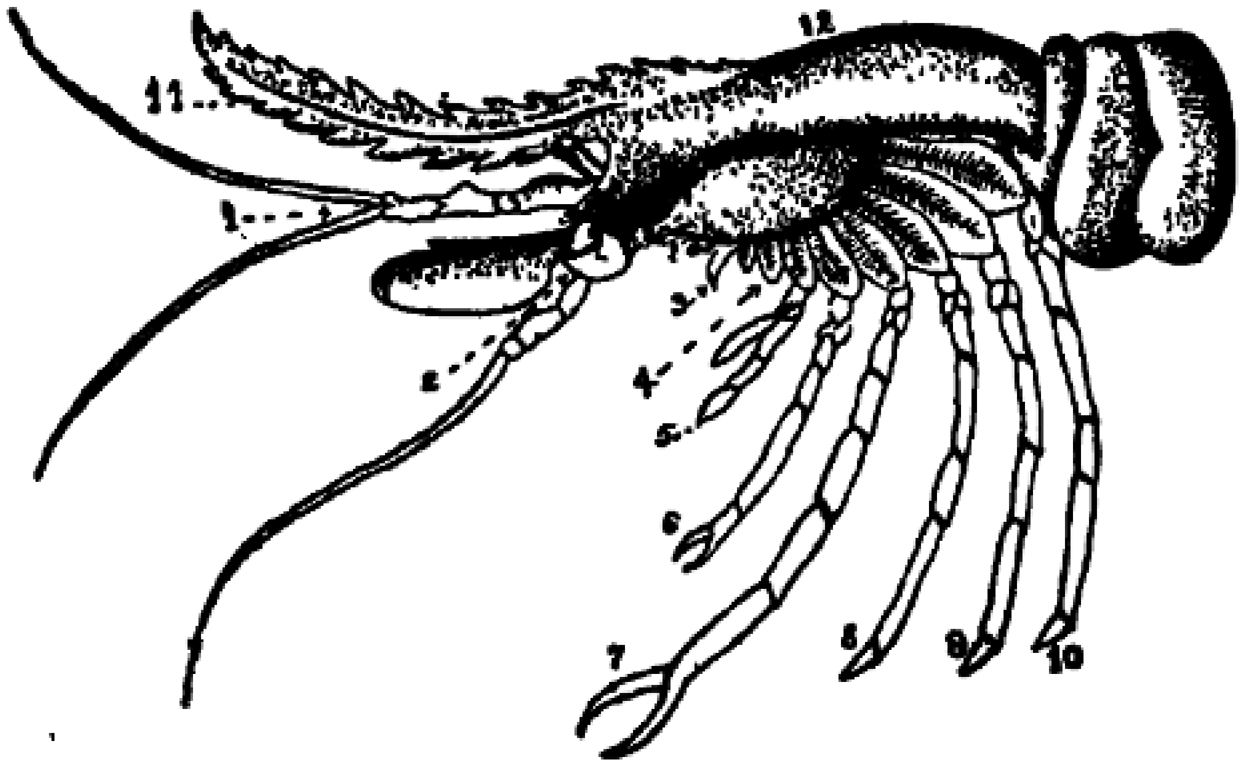
The blood in the various organs of the body flows through a network of hæmocoelic lacunae or sinuses distributed throughout the body and is finally received into a pair of ventral sinuses which are situated below the hepatopancreas and the flexor muscles of the thorax. These two adjacent ventral sinuses communicate with each other. These sinuses are protected ventrally by the sterna and the endophragmal skeleton.

From the ventral sinuses blood is carried to the gills on each side by six definite channels called the **Afferent branchial channels.** These channels are also lacunar in character. Of the branchial channels, the last five send blood to the pleurobranchs while the first channel supplies the two arthrobranchs and possibly to the podobranch. In the gills the blood circulates and is aerated. The aerated or oxygenated blood returns to the pericardial sinus through the six pairs of **efferent branchial channels** (branchio-cardiac canals). It is seen that the afferent and efferent channels pierce the wall of the thorax one above the other and therefore, on removal of a gill, two openings are exposed at the root of each gill.

Respiratory System : 1951

The respiratory organs of the prawn consist of the lining of the carapace, three pairs of epipodites, and eight pairs of gills or branchiae, all of which are situated in the large but compressed gill-chambers, one on each side of the thorax. Each gill-chamber is enclosed between the branchiostegite on the outer side and the wall of the thorax on the inner and is in communication with the exterior along its anterior, ventral and posterior borders but is closed along its dorsal aspect. The thin inner lining of the branchiostegite contains blood-lacunae and is constantly bathed in fresh water, thus forming a respiratory surface.

The respiratory system consists of eight Gills on each side which lie inside the Gill Chamber. The gill chamber is bounded on the out-side by the Branchiostegite and by fused Epimera of the cephalo-thoracic segments on the inside. The chamber is open in front, below and behind. A current is produced by the scaphognathite within the branchial chamber. The gills are of three different names according to their position. When a gill is attached to the basal podomere (coxa) of an appendage, it is known as a **podobranch**; when attached to the arthrodial membrane connecting the appendage to the body, it is called an **arthrobranch**; but when it is attached to the lateral wall of the segment to which the appendage belongs, the gill is called a **pleurobranch.** Starting from the anterior end, we find that the first maxilliped bears no gill but only a bilobed epipodite. The second maxilliped bears both a podobranch and a small epipodite. The third maxilliped bears two arthrobranchs and a small epipodite. Gills of the segments of



1—1st antenna, 2—2nd antenna, 3—Scaphognathite, 4—Gill, 5—3rd maxilliped, 6 to 10—Legs, 11—Rosturm, 12—Carapace.

the five walking legs, are five pleurobranchs. The first gill is a podobranch being attached to the base of the second maxilliped. The second and third gills are arthrobranchs being attached to the arthrodial membrane of the third maxilliped. The remaining five gills are pleurobranchs.

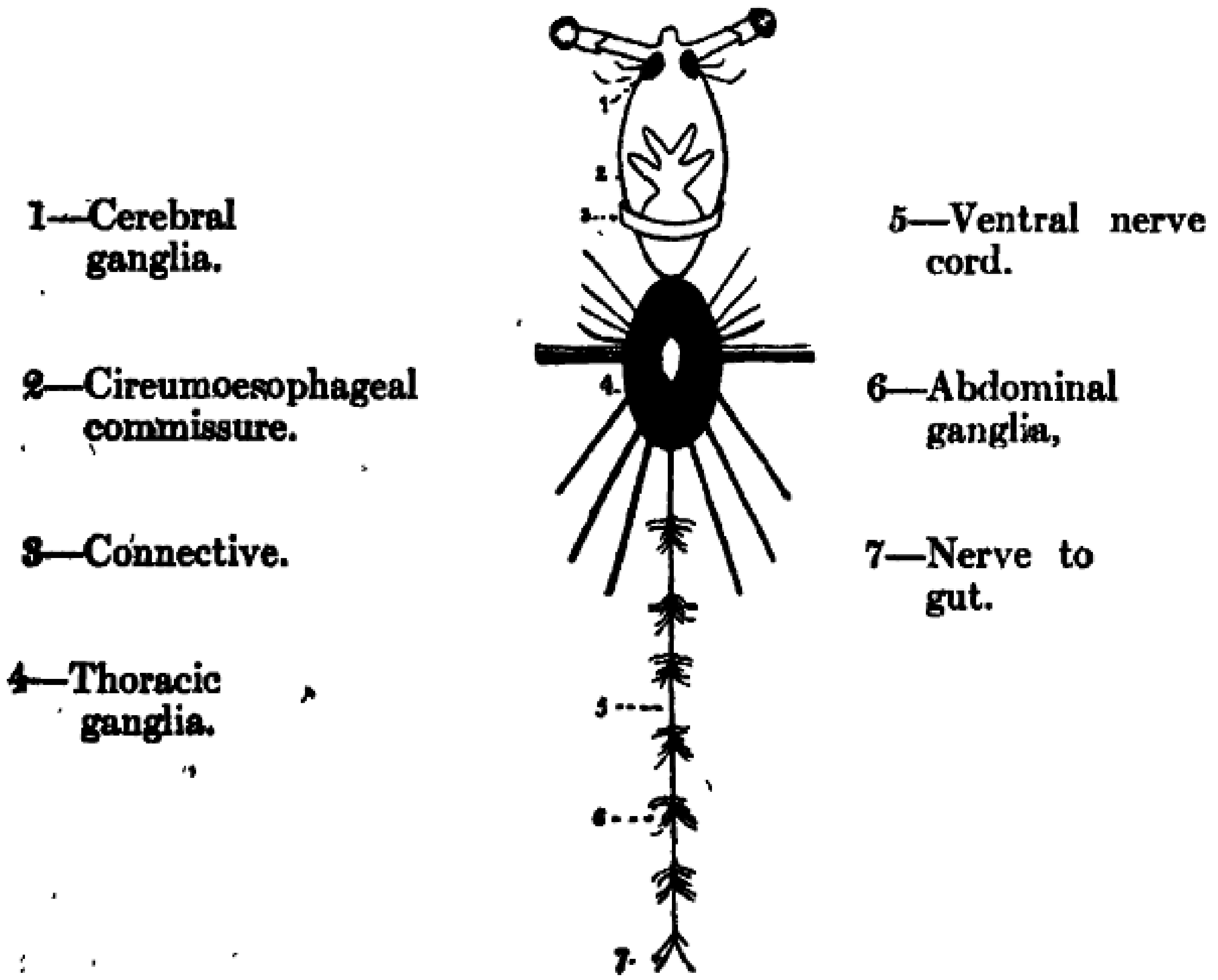
The epipodites are simple leaf-like plates attached to the coxal joints of the three maxillipeds and each outgrowth of the epipodite forms a simple primitive type of gill. The epipodites lie in the anterior part of the gill-chamber below the scaphognathite; of the eight gills, seven are exposed on removal of the gill-cover but the eighth lies hidden beneath the dorsal part of the second gill.

The gills are thin walled and each gill consists of numerous delicate plates arranged like the leaves of a book. The plates have a stout axis. The gill axis is attached to the side of the animal. The axis carries an Afferent vessel and an Efferent vessel. The thin-walled gill exchanges CO_2 and takes up oxygen from the current of water and thus the blood becomes oxygenated. The scaphognathite keeps vibrating incessantly so as to produce a continuous current of water flowing through the gill-chamber. Water enters the gill-chamber along the posterior and ventral margins of the branchiostegite; it then passes over the gills and reaches the antero-dorsal depression of the gill-chamber, wherefrom it is expelled out at the anterior end by the baling action of the scaphognathite. The vibratory movements of the scaphognathite are supplemented by the movements of the whip-like exopodites of the maxillipeds which whisk away from the sides of the animal the water which the scaphognathite has baled out. The gill-chamber containing the epipodites and gills and the lining of the carapace are thus constantly being bathed in a current of fresh water.

Excretory System :

The excretory organs of the crustacea comprise two pairs of glands: (*a*) the antennary glands opening at the bases of the antennæ and (*b*) the maxillary glands

Nervous system of prawn.



opening at te bases of the maxillae. Both types of glands do not function at the same time; as a rule, one succeeds the other. In Decapoda like prawn, the maxillary glands form the larval kidneys while the antennary glands form the functional kidneys of the adult. The kidneys of the adult prawn are a pair of antennary glands.

The Excretory organs are also known as Green glands. The glands are situated in the Head and their ducts open at the base of the second antennæ. Each renal gland consists of a single much coiled tubule with connective tissue. The renal branch of the Antennary artery comes in contact with the Renal tubule. The blood gets rid of the nitrogenous waste products in the cells of the Renal tubule. There is a dorsal Renal sac which lies dorsal to the stomach and below the carapace. The sac contains fluid and is connected with the Reproductive organs. There are two ducts from the Dorsal Renal sac which pass to the ventral side and open into the Renal saccules, one on each side. The saccules are situated on the inner side of the Renal glands. The saccules send two ducts to the excretory apertures of the two sides.

Besides the antennary glands, the integument is believed to be an important organ of excretion.

Nervous System :

The nervous system resembles the nervous system of the Leech. The Brain or cerebral Ganglion or supraœsophageal Ganglion is situated between the green glands. It gives off nerves to the Eyes and the Antennæ. It sends below two circumœsophageal Commisures to join behind the œsophagus. Below it, is the Thoracic Ganglion supplying the third Maxillipeds. Here the fusion of ganglia has taken place forming thoracic ganglionic mass. In the circumoesophageal commissures a loop is formed by the fine nerve cords round the œsophagus. This is known as Postoesophageal loop. The Thoracic ganglionic mass is perforated by the sternal artery. It supplies nerves to all the appendages of the cephalothorax. The thoracic ganglionic mass gives rise to a double ventral nerve cord. This cord has six ganglionic swellings corresponding to six segments. Each ganglion gives rise to nerves which supply the muscles. The sixth ganglion supplies the sixth segment and the telson.

The nervous system therefore consists of: (*a*) a pair of supraoesophageal ganglia or the brain connected by (*b*) a pair of circumoesophageal commissures with (*c*) a ventral nerve-chain of paired ganglia lying in the mid-ventral line along the whole length of the body of the prawn and (*d*) the visceral nervous system consists of a number of small ganglia in connection with the œsophagus and the stomach.

Sense Organs :

The setæ or hairs distributed all over the body may have the function of tactile organs. The sensitiveness of the Antennæ serves the animal to search for food.

Organs of smell or Olfactory organs :—

The setæ on the outer flagellum of the first antennule may have the function of smell.

Eyes or sense of sight :—

There are two stalked compound Eyes. Each eye is compound *i.e.* consists of a large number of simple visual elements called ommatidia or ocelli. Each Eye has a number of elements called Ommatidia. The Eye is black owing to pigments in some of its cells. It is covered with a colourless portion of the cuticle called Cornea which is divided into a number of square facets, each of which corresponds to an ommatidium. Each ommatidium has a complex structure. Each is an elongated body consisting of a number of cells derived from the Epidermis with refractive bodies secreted by them. Beneath the corneal facet lying at the surface of the eye are situated a pair of corneagen cells which secrete a new cornea when the old one is discarded during ecdysis. Beneath the corneagen cells lie tall cells called the cone-cells or vitrellae. These cells surround the crystalline cone. Beneath the crystalline cone lies the rhabdome which is surrounded by retinular cells. The rhabdome and the retinular cells together form the receptor or retinal part of the ommatidium. The innermost cells form a group called Retinula whose inner ends are continued into nerve fibres. It is regarded that a mosaic of images is combined in the nervous system to give a single impression of objects seen by the prawn.

Statocyst or **Otocyst** or organ of Hearing :—

These are a pair of sacs at the base of the first antennules and are connected with nerves. The sac has a lining of hairs which are connected to the nerves. The sacs are filled with sand grains. This organ is a balancing apparatus of the animal. The sand grains move against the hairs and the direction of the body is perceived through them. Formerly the organ was regarded as an organ of hearing but recently experiments carried on with moulting prawn disprove the former idea.

Iron grains were placed inside the sac and a magnet attracted the iron grains which changed the direction of the animal and proved their balancing power. The statocysts have been shown to be organs for perceiving the direction of the force of gravity.

Reproductive System :

The sexes are separate. These organs lie above the gut and below the pericardium. The organs in both sexes have lobes. Two ducts open to the base of the third and fifth thoracic legs (Maxillipeds). The females are smaller than the males of the same age.

Male :

The testes are two in number and the anterior portion is attached to the renal sac in front. The Vasa Deferentia or sperm ducts are much coiled tubes beginning from the testes and ending by a shorter portion at the base of the fifth legs. Each spermatozoon has a cup-like body and a stiff tail. The testes fuse at the anterior part but are free posteriorly. The end of the vas deferens is dilated and forms vesicula seminalis.

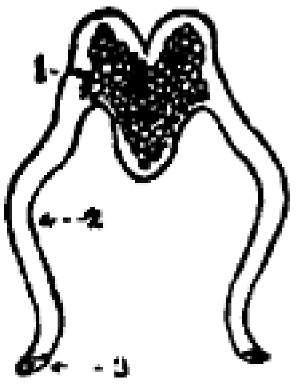
Female :

There are two ovaries which lie near the Renal sac. Ova are produced within them. The two ducts from the ovaries are short and open at the base of the third thoracic leg. The ova are large, each with a nucleus and plenty of yolk material.

Development :

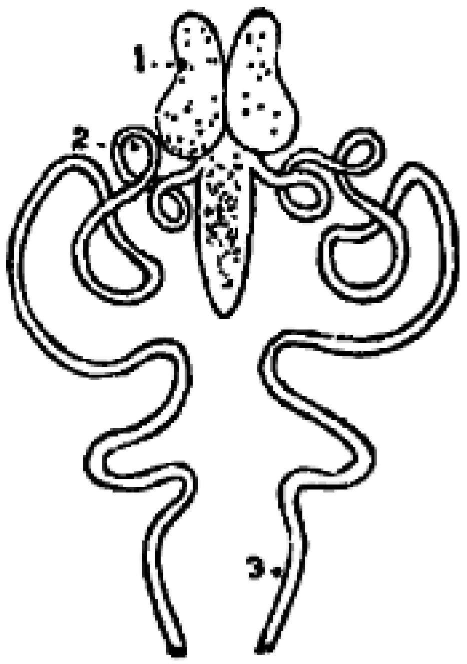
Generally pairing takes place in september and October *i.e.* just after the rains. After the ovum is fertilised it is held fast in the swimmerets. Segmentation takes place there and a larva hatches out which is called the Zoea larva. The larva moults several times until the adult form is reached. This is called the Metamorphosis of Prawn. The hard covering is shed from time to time to make room for growth taking place in the meantime. The Zoea has a cephalo-thorax and a segmented abdomen. The appendages of the cephalo-thorax are all biramous and have two pairs of antennæ, one pair of mandibles, two pairs of maxillæ, three pairs of maxillipeds, three pairs of thoracic legs. The abdomen has no appendage. The carapace has a small rostrum. There is one median Eye called Nauplius Eye in addition to the pair of compound Eyes. After several moults the Zoea becomes a Schizopod or Mysis. It differs from the Zoea in that two or more thoracic appendages appear. The Mysis moults several times and reaches the adult or prawn stage. Several modifications occur in the cephalothoracic appendages, the nauplius Eye is lost and the abdominal appendages appear.

Ovary of prawn.



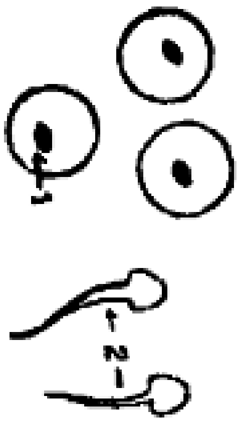
1—Ovary.
2—Oviduct.
3—Opening.

Tests of prawn.



1—Testis.
2—Vasdeferns.
3—Opening and last part.

Sperms and ova of prawn.



1—Ovum.
2—Sperm.

Regeneration :

Prawn can reconstruct a lost limb by regeneration. This is helpful because the animal can escape from its enemy by leaving the limb. This power of regeneration is known as Autotomy. When the leg is separated blood clots the injured part and gradually the limb grows with each moult.

Bhetki :

The fish is scientifically known as Lates Calcarifer. The name of each animal or plant in Biology has two parts. The first part refers to the **Genus** and the second part refers to the **Species** to which the animal belongs. This is known as Binomial Nomenclature. The great Biologist Linnaeus first found out the value of such nomenclature and promulgated it.

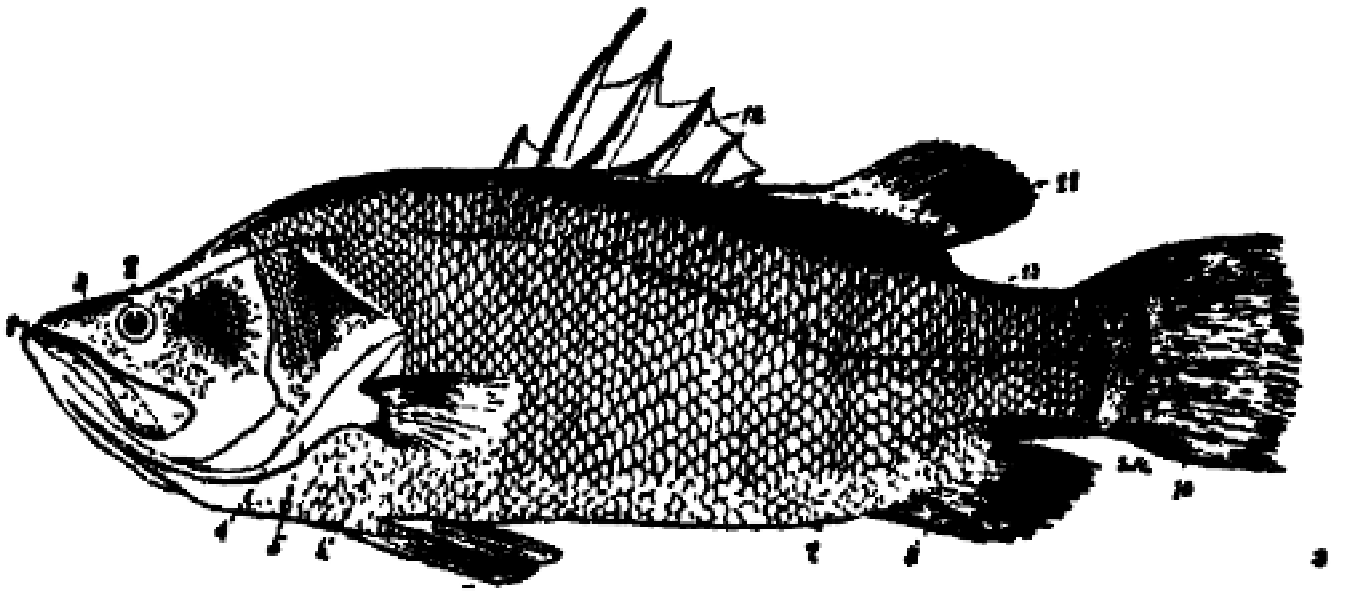
The animal is a type of Chordata and specially of Vertebrata. The higher animals all have a structure called Notochord which is generally dorsal in position. There are some lower Chordates where the Notochord is either rudimentary or confined to the larval condition before the attainment of the adult structure *e.g.*, Balanoglossus, Ascidian etc. The "Bhetki" has a vertebral column which is derived from the Notochord. The case of the notochord is replaced by a bony column called the Vertebral column and hence the name Vertebrata. Therefore the presence of vertebral column is a characteristic feature of the vertebrata which is generally dorsal in position. The second characteristic is the presence of openings in the back of the throat called Gill slits. These Gills are richly provided with blood vessels in the Bhetki and help the animal in carrying on the process of respiration but in the more advanced groups like the Guineaping or man the clefts are only present during the developmental stages of the fœtus and are absent in adults. The third characteristic is the presence of the Brain and the spinal cord in the form of a tube. The fourth characteristic is the presence of a Cœlome and a Heart which is ventral in position.

Habitat :

The fish Bhetki occurs in the saline estuaries of Bengal. It is used largely by the inhabitants as an article of food. The size varies from four inches to four feet in length.

External Characters :

The fish has a **head, trunk** and a **tail.** There is no neck. There is a distinct line visible on each side of the animal (which is flat from side to side) which is known as the **Lateral line** provided with sense organs extending from head to tail. The whole body is covered with scales. The scales are covered by the epidermis which secretes a slimy mucus which,



1—Mouth, 2—Eye, 3—Nostril, 4—Operculum, 5—Branchio-Stegal membrane, 6—Pectoral fin, 7—Pelvic fin, 8—Anal fin, 9—Anus etc., 10—Caudal fin, 11—Dorsal fin No. 2, 12—D. fin No. 1,13—Lateral line.

makes the animal difficult for a catch with hand. There are a pair of nostrils on each side. There are two eyes but they are not provided with an eyelid but a transparent membrane covers each eye which is called **Nictitating membrane.** There is a large mouth inside which palatine teeth are found when the mouth is opened. On the roof of the mouth is a double row of vomerine teeth. There is a large tongue which forms the floor of the mouth. The region from the mouth to the **Operculum** is known as the Head. The trunk extends from the Operculum to the anus and the region behind the anus is the tail.

Apertures of Bhetki :

(1) The mouth is large and terminal.

(2) Double nostrils on each side *i.e.*, each Olfactory sac has two apertures externally, the anterior one is provided with a flap-like valve.

(3) The gill-chamber has a bony covering called Operculum which shelters the gills or respiratory organs of each side. The operculum is continued into a slimy membrane supported by bony rays called respectively Branchiostegal membrane and Branchiostegal rays.

(4) At the posterior ventral side near the anal fin there is a slight depression of the skin having three apertures called the Anus in front, Genital in the middle and Urinary behind.

Fins :

The appendages of the fish are called the **fins.**

Some are unpaired (single) and median while the others are paired and lateral. They are :—

(1) **Dorsal fin,** median and unpaired.

(2) **Posterior Dorsal fin,** median and unpaired.

(3) **Caudal fin** or **tail.** It is of the homocercal type *i.e.,* symmetrical in form. It is the chief organ of locomotion.

(4) **Single Anal fin** behind the Anus.

(5) **Paired Pectoral fins** just close to the Gill' opening.

(6) **Paired Pelvic fins** on the ventral side of the animal.

Muscles of the Body :

The muscles are known as Myotomes or Myomeres. These are arranged segmentally on the two sides of the body. There are two sets of such muscles one below the other separated by the lateral line. The muscle segments are V-shaped and each segment is connected with the other by connective tissue.

There are some other muscles which are used for controlling the fins. These muscles are voluntary.

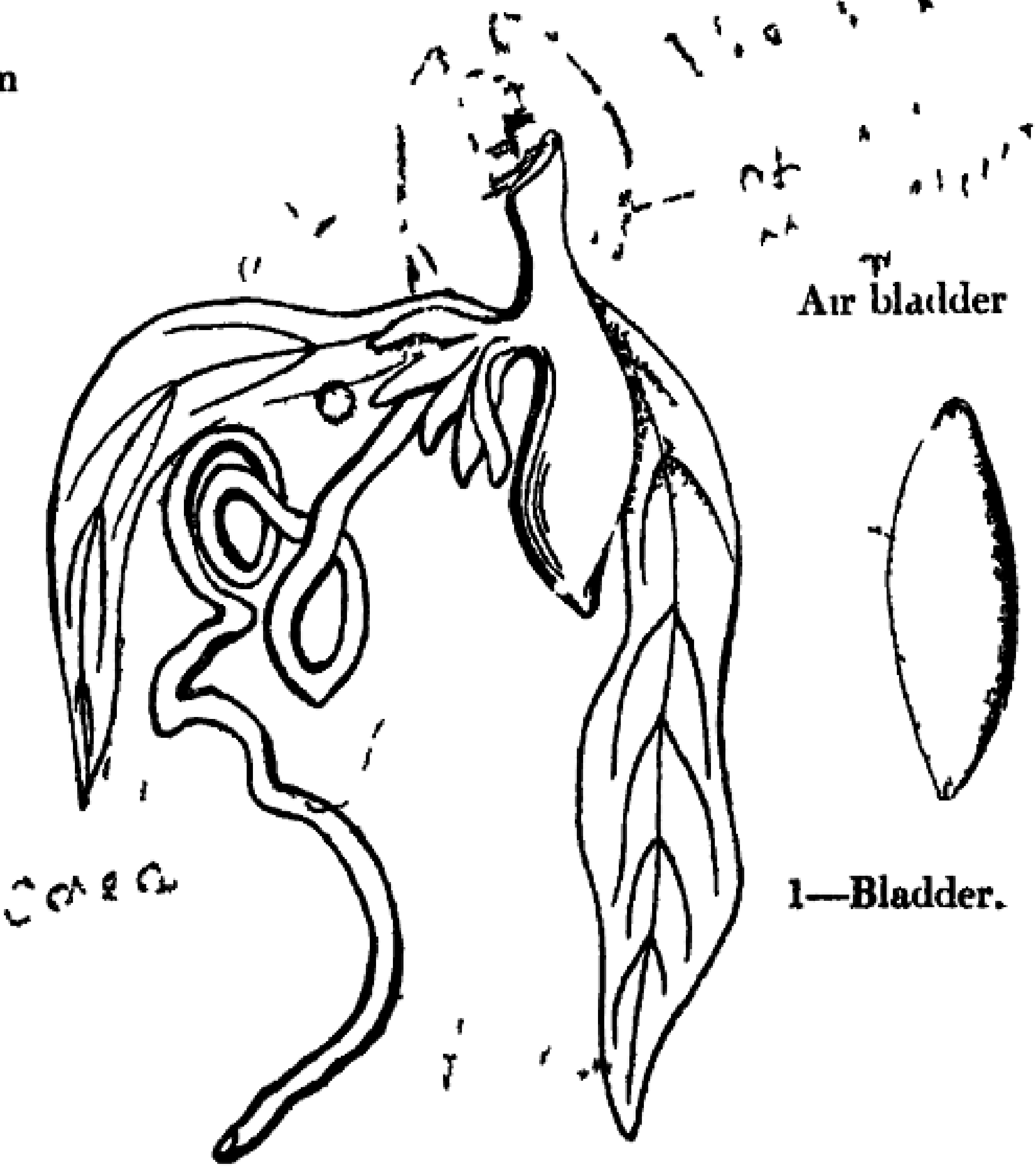
Coelome :

The body cavity is called the Cœlome. The largest cavity is the abdominal cavity containing the abdominal organs. There is another cavity called the Pericardial cavity, containing the Heart. The abdominal cavity is lined by a layer of Epithelium called Peritoneum. The layer covering the organ or organs is called the Visceral layer, while the layer which lines the wall of the body-cavity is called the Parietal layer. The two layers *viz.*, visceral layer and parietal layer form a continuous layer on the dorsal side below the spinal column which is known as the Mesentery. This is used to hold the abdominal organs in position.

Alimentary System :

The mouth is wide and leads into a part called the Buccal cavity and is continued into the Pharynx. The **Pharynx** is perforated on each side by four apertures called **Gill-slits.** The Pharynx is followed by a short **oesophagus** which opens into the elongated **stomach.**

Alimentary system



There are both palatine and vomerine teeth. They are mainly used for preventing the food from slipping out of the mouth. They are not implanted in sockets and are not used for cutting or chewing.

The stomach has two ends. The end towards the pharynx is called the cardiac end. The other end from which the intestine begins is called the Pyloric end. The pyloric end has a number (5) of blind pouches called **Pyloric caeca.** The pyrolic end is provided with a valve called Pyloric Valve. The pyloric caeca open into the first part of the intestine. The intestine is a much coiled tube which ends in the Rectum. The Rectum opens by an aperture called Anus. There is no distinct Pancreas. The coils of the intestine are richly laden with fat and they are kept in position by the mesentery. (The rectum is not clearly distinguishable).

The Liver has two long lobes and a small and has a gall bladder. The spleen lies on one side of the intestine.

Swim-Bladder :

There is a thin sac just behind the alimentary canal and in front of the Vertebral column. This is called the Air-Bladder or Swim-Bladder. The bladder has two lobes called the anterior and posterior lobes. The air-bladder is a hydrostatic organ *i.e.*, it functions as a float *viz.*, it renders the fish bulk for bulk of the same weight as the water in which it lives that is, it gives buoyancy to the fish according to various depths of water. It arises as a diverticulum of the alimentary canal.

Functions of the Air-bladder :

(1) The most important function of the air-bladder is hydrostatic *i.e.*, it acts as a float for the fish as already explained.

(2) It acts as an accessory respiratory organ in some fish.

(3) It acts as a sound producing organ by the vibratory movements in the gases contained inside the organ due to the rapid contraction of the muscles associated with the walls of the air-bladder.

(4) It serves as an accessory organ of hearing in some fish.

The gases contained in the air-bladder are oxygen 65%, nitrogen 30% and CO_2 5 %.

Heart and Vascular System :

The heart of Bhetki consists of a sinus Venosus, an auricle and a ventricle. The heart lies within a sac called Percardium.

The Sinus Venosus is a thin-walled sac lying posteriorly and receives the impure or venous blood of the body from the Anterior and Posterior veins.

The Auricle is placed ventrally to the sinus venosus. The blood is directed by valves from the sinus venosus to the Auricle and not otherwise. The auricle has thin walls.

The Ventricle is thick-walled. Its contraction forces the blood into the ventral Aorta. The aperture between the auricle and the ventricle is guarded by valves and

Systemic veins bring blood directly to the Heart. Portal veins have to bring the blood through some intermediate structure. The Afferent Branchial Arteries although they have been included under Arteries may be described as real veins as they carry impure blood to the Gills for oxygenation.

There are two principal veins in the anterior part of the animal bringing blood from the head region called Anterior Cardinal Veins. The two veins coming from the lower portion are known as Posterior Cardinal Veins. The Anterior and Posterior Cardinals of each side unite to form a common vessel called Precaval Vein or Ductus Cuvieri before opening into the sinus Venosus. There are two veins also coming from the Liver to the sinus venosus called Hepatic Veins. The right posterior cardinal is a continuous vein from the tail region. The right posterior cardinal lies ventrally to the kidney. These are all systemic veins.

Portal Veins :

There is a Renal portal system. Blood from the region of the tail is collected by the Caudal Vein lying along side the Caudal artery. Before entering the kidney the Caudal vein divides into two Renal portal veins lying on the back portion of the kidney. The right Renal portal vein is continuous with the right posterior Cardinal vein. The left Renal portal vein is broken down into capillaries and then the left posterior cardinal vein is formed by a number of small veins from the substance of the kidney.

Hepatic Portal System :

The hepatic portal system is formed by a number of veins bringing venous blood from stomach, intestine, and rectum, and enters the Liver by a single vein called Hepatic portal vein. There is a system of capillaries in the Liver and ultimately the blood passes to the sinus Venosus by two Hepatic Veins.

Blood :

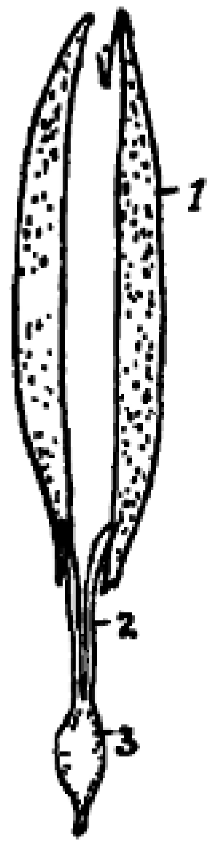
The blood of Bhetki consists of a liquid portion called the Plasma, and two kinds of corpuscles float in it. There are white blood corpuscles and red blood corpuscles. The white ones are nucleated and amœboid. The red cells are oval nucleated and contain a red pigment called Hæmoglobin.

Circulation :

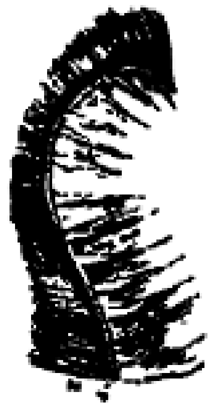
Venous blood of the body enters the Heart through the two precaval veins. From the sinus Venosus, the blood passes to the Auricle, then to the ventricle and by means of the ventral aorta to the Gills for purification. After oxygenation pure blood is supplied by the Cephalic arch and the Dorsal Aorta to the different parts of the body. There is a system of capillaries by which the arteries communicate with the veins. The arterial blood after ramifying in the tissues by fine branches becomes impure and then enters the capillaries and then goes to the veins; thus a continuous channel is established. The contraction of the Heart pumps the blood to different parts of the body. The cycle is repeated all the time the animal is alive.

Excretory System :

There are two elongated kidneys, which begin almost below the Gill arches and extend to the end of the abdominal cavity. They are the second step in the development of the kidneys and are known as Mesonephros. The surface of the kidney is perforated by fine apertures through which the kidneys have communication with the peritoneal cavity. The two kidneys are almost fused in the middle line. Each kidney has a passage beginning near the middle, passing downwards joins up to form the Urinary Bladder. The urinary bladder opens by an aperture to discharge the waste products of the body. The kidneys lie just on the ventral side of the vertebral column.



1—Kidney,
2—Ureter,
3—Bladder.



1—Gillarch,
2—Gill filament.

Respiratory System :

The respiratory organs of the fish Bhetki are the gills. They lie in a chamber which is covered externally by a plate of bony structure called Operculum. The operculum consists of four bones called Operculum, Pre-operculum, Inter-operculum and Sub-operculum. The bones are moved by muscles. There is a membrane behind and below the operculum which is called the Branchiostegal membrane which can perfectly close the chamber. This bony mechanism is always opening and closing to drive out the incoming water from the mouth during the whole life time of the animal. The Gills are placed on four Gill arches separated by five Gill clefts. The Gill chamber opens internally into the Pharynx. Each Gill has two book-like folds consisting of a number of Gill filaments. The arches carry the afferent and efferent vessels. The filaments are richly supplied with fine blood vessels called Capillaries.

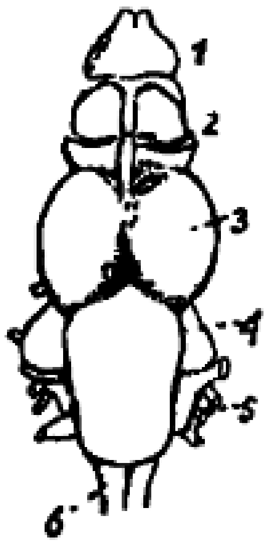
Mechanism of Respiration :

The water enters the mouth of the fish and passes through the Gill clefts to the Gill chamber which drives the water out by lifting the Operculum. The process of respiration consists of two different actions *viz.*, Inspiration or the taking in of water and expiration or driving out of water. During inspiration the water enters the mouth and while passing through the clefts the water washes the gill filaments when oxygen is supplied to the blood inside the capillaries there. This oxygen of course comes dissolved in the water. The waste product in the form of CO_2 is exchanged for it almost simultaneously and the CO_2 passes out dissolved in water. The Hyoid arch is retracted when the mouth is opened in taking food or in inspiration and at the same time the Gill aperture is closed. But the Gill aperture opens when swallowing food and at the same time the Hyoid arch is brought forward.

Brain and Nervous System :

The Brain consists of two Olfactory lobes in front. The cerebrum lies below them. The cerebrum consists of two hemispheres having a longitudinal fissure between them. The thalamencephalon comes next and is partly covered by the Cerebrum. On the ventral aspect is the Infundibulum to which is attached the Pituitary body. In the dorsal side is the minute Pineal body. On the ventral aspect there is a crossing of the Optic nerves. There are two large optic lobes. Then comes the Cerebellum which is large and median in position. The final part is the Medulla Oblongata continued in the Vertebral column as the Spinal Cord which runs down to the tail.

Brain



1—Olfactory,
2—Cerebrum,
3—Optic lobe,
4—Cerebellum,
5—Nerves,
6—Medulla oblongata.

Cranial Nerves :

There are ten pairs of cranial nerves :—

1. Olfactory supplying the nostril.
2. Optic Nerves supplying the Eyes.
3. Oculomotor Nerves arise from the mid-brain and supply four out of six muscles of the Eyeball.

4. The Pathetic Nerve arises from the point between mid-brain and medulla oblongata. It supplies the superior oblique muscle of the Eye.
5. Trigeminal Nerve is of great size and wide distribution. It arises from the side of the medulla. It has a ganglion near its origin called the Gasserian Ganglion. It divides into two branches *viz.*, Ophthalmic and Mandibular. The Ophthalmic again divides into deep and superficial branches which supply the skin near the mouth and the orbit. The Mandibular nerves supply the jaws.
6. Abducent is a small nerve arising from the Medulla and supplies the muscle of the Eye.
7. Facial arises from the Medulla also it has two branches, *viz.*, Palatine supplying the mucous membrane of the palate and the Hyomandibular supplying the Lower jaw and the Hyoid arch.
8. Auditory Nerve supplies the organ of hearing.
9. Glossopharyngeal arises from the medulla and supplies the first branchial arch.
10. Vagus or Pneumogastric arises from the side of the Medulla and has a ganglion called Vagus Ganglion. It gives off nerves called Branchial nerves to the Gill-slits. The Vagus also gives off a Cardiac Nerve to supply the Heart and a Gastric branch to the stomach. A nerve arises in fish from the Vagus and is known as the Lateral Nerve which supplies the Lateral line sense organs of fish.

Spinal Cord :

The Spinal Cord is a long continuation of the Brain. Nerves arise from it and are known as Spinal Nerves which supply the various parts of the body except the cranial portion.

Sympathetic System :

There are two cords of Nerves on the two sides of the Vertebral Column. The sympathetic cords are united at the anterior portion with the Vagus. The cords run towards the tail by the sides of the precaudal vertebræ and pass along the hæmal canal by the side of the caudal artery.

Sense Organs :

Tactile Sense Organs :

These are found in the form of cells of the Epidermis on the surface of the body.

Olfactory organs are represented in the nasal sacs supplied by the Olfactory Nerves.

Taste organs occur as Tastebuds in the Pharynx.

Ear :

There is only Internal Ear.

There are two eyes which are complicated organs.

Reproductive System :

The animals are either male or female. The male organs are the testes in the form of sacculated tubes. The testes are paired organs and extend almost to the whole length of the abdominal cavity. Each testis has a duct which joins with the other duct and open to the exterior by a single aperture. The ovaries are also sacculated organs and are much wider than the testes. Sometimes the ovaries are filled with numerous ova.

Ovary. Testis

1—Testis,
2—Duct.

They have ducts which unite to open to the exterior by a single aperture between the Anus and the excretory aperture. The sexual organs are not well-developed in the young fish.

Skeleton :

The skeleton of Bhetki consists of a cranium which contains the Brain. The cranium consists of a number of bones but the detailed study of which is not meant for the Intermediate students.

The bones of the cranium are :—The dorsal part of the skull consists of two bones called Parietals, in front of which are the two frontals. On the side of the parietal bone is the Pterotic bone. The sphenotic lies in front of the Pterotic. Below the Sphenotic lies the Orbital which is seen from the side. The Mesethmoid bone lies in front of the Frontals with two lateral Ethmoids. The Nasal bone lies in front of the Lateral Ethmoid. The Maxilla and Premaxilla lie in front of the Mesethmoid. The Jugal bone is seen from the side articulating with the first orbital. There are five otic bones on each side of the skull *e.g.*, Epiotic, Opisthotic, Pterotic, Prootic and Sphenotic. At the back of the skull there are four bones *e.g.*, Basi-occipital, two lateral occipitals, called Exo-occipitals and a Supra—cocipital bone. There is a large hole below the Supra-occipital called the Foramen Magnum through which the Brain communicates with the spinal cord.

On the ventral side the Basi-occipital has in front the long Parasphenoid bone. The Vomer lies in front of the Parasphenoid. At the side of the Parasphenoid is the lateral Alæsphenoid one on each side.

On the lateral aspect the Pterotic bone has the Hyomandibular bone on each side. The Hyomandibular has a triangular operculum which covers the Gill-chamber. There is another bone called Symplectic. The Pre-operculum lies below the Hyomandibular. The Sub-operculum lies below the Operculum and another bone called Inter-operculum lies in front of the Sub-operculum.

The lower jaw or Mandible consists of a Dentary in front, Angular below and Articular behind the Dentary. They are all fused bones.

Hyoid Apparatus :

The bone which articulates with the Hyomandibular above is the Epihyal, below are the Ceratohyal and the Hypohyal fused together. They give off curved bones called the Branchiostegals. There is another bone called Basihyal further in front and Glossohyal which supports the tongue. The Urohyal lies backwards to Basihyals.

There are four Gill arches. The arches are fused with some median bones behind the Glossohyal. The arches bear the Gill filaments from their lower border.

There are two girdles which form the appendicular skeleton *e.g.*, Pectoral Girdle and the Pelvic Girdle. The Pectoral Girdle is well developed but the Pelvic is not so. The Pectoral Girdle consists on each side of a Supra-clavicle, and L-shaped clavicle and the rodshaped Postclavicle. The Scapula lies below the clavicle. The coracoid lies below the clavicle with a large foramen. The fins are supported by small bones called Pterygiophores and some fin-rays.

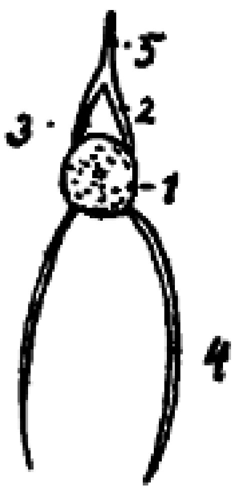
The Axial Skeleton

The Axial skeleton of Bhetki consists of the Vertebral column. There are two kinds of Vertebræ *e.g.*, Precaudal and Caudal. Each vertebra of the Precaudal region consists of a biconcave solid centrum called Amphicœlous Centrum from which two arches join and is called the Neural Arch and bears a spine on the dorsal side called Nerual Spine and the sides of the arch bear two transverse processes. Ribs come out from the two sides of the Centrum. The Caudal Vertebræ differ from the pre-

Caudal.

1—Centrum,
2—Neural canal,
3—Neural spine.

Precaudal.

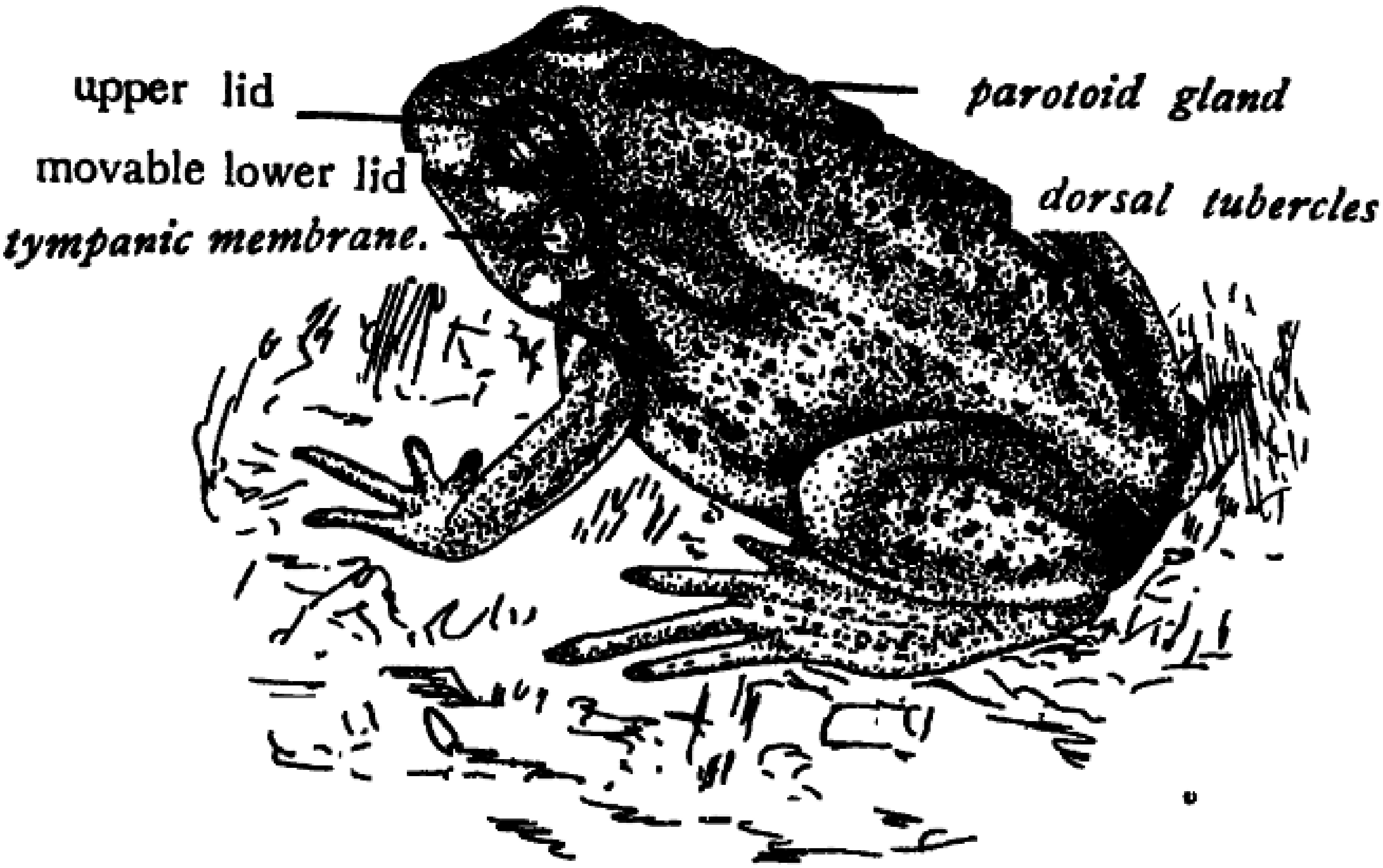


1—Centrum,
2—N. arch,
3—N. canal,
4—Rib,
5—Spine.

caudal in that the transverse processes join up to form a second arch called Haemal Arch in addition to the neural arch. The last bone of the axial skeleton turns upwards and is known as the Urostyle. There are articular processes in each vertebra called Prezygapophysis in front and Postzygapophysis behind which keep the vertebral column in position.

The Toad :

The scientific name of Toad is **Bufo melanostictus.** The animal belongs to the class **Amphibia.** The word Amphibia means double life because the animals have to pass the early stages of their lives in water as **Tadpoles** which are peculiar fish-like larvæ breathing by gills and afterwards become converted into land animals as adult



Toad.

Toads breathing by lungs. The other familiar member of this class is the frog. The toads are very common in Bengal and the peculiar croaking sound produced by the males is known to all.

Difference between Toads and Frogs :

Toad.	Frog.
1. The skin is dark.	1. The skin is bright yellow with stripes.
2. Short body.	2. Long body.
3. Webs in the digits of the hind limb are short.	3. The webs are longer in the digits of the hind limbs than in toad.
4. Skin is very glandular and warty.	4. Skin is not warty.
5. Omosternum is absent.	5. Omosternum is present.
6. Epicoracoids twisted.	6. Epicoracoids are overlapping.
7. Plentifully distributed in Bengal.	7. Rarely found in Bengal.

External Features :

The animal has a peculiar and characteristic squatting posture. There is a **head,** a **trunk** but no **neck** nor a tail in the adult. The skin is rough and warty, with multiple poison glands in the shape of pimples; these glands are more numerous on the dorsal surface than on the ventral. The colour of the Skin is paler on the ventral aspect. The head is triangular in form—the apex representing the snout. At the sides of the head, there are two prominent eyes. Each eye has a movable upper eyelid, an immovable lower eyelid and a transparent movable nictitating membrane. Behind each eye, there is a circular spot called **tympanum** which represents the external ear. Behind each tympanum, there is a large aggregated gland called the **parotid** gland.

The trunk is provided with two pairs of limbs. Each **forelimb** has three segments—an **arm** or **brachium,** the middle segment or the **forearm** or antebrachium and the distal third segment or the **hand** or **manus.** In the hand may be distinguished a **wrist** or **carpus,** a **palm** or **metacarpus** and fingers or digits of which there are only four, the thumb or pollex being absent. In the males, there is a pad of skin called thumbpad on the inner side of the first digit similarly each hindlimb has three segments. The first or proximal segment is known as the **thigh** or **femur,** the second or middle segment as the **Shank** or **Crus** and the third segment as the **foot** or **Pes.** The foot has an ankle or tarsus followed by the **metatarsus** and then comes the webbed toes or digits which are five in number. The lower surface of the foot is called the **plantar** surface and the similar surface of the hand is called the **palmar** surface. The webbed hindlimb is rarely used for Swimming.

Skin :

The skin of toad is a thin protective covering. It contains the glands of several kinds and some pigment cells. The toad sheds off the skin from time to time. This process is known as **ecdysis.** The change of colour noticed in frogs and toads is due to the contraction and expansion of the pigment cells of the skin. The skin is devoid of any sweat-gland consequently it has very little excretory function. On the other hand, the skin is richly supplied with blood and has a part in respiration.

Apertures :

There is a large horizontal slit at the end of the snout called the **mouth.** At the posterior end of the trunk, there is a small aperture called the **cloacal aperture.** There are a pair of minute apertures called the **external nares** situated one on either side of the snout just above the slit of the mouth

Body-wall and Body-cavity :

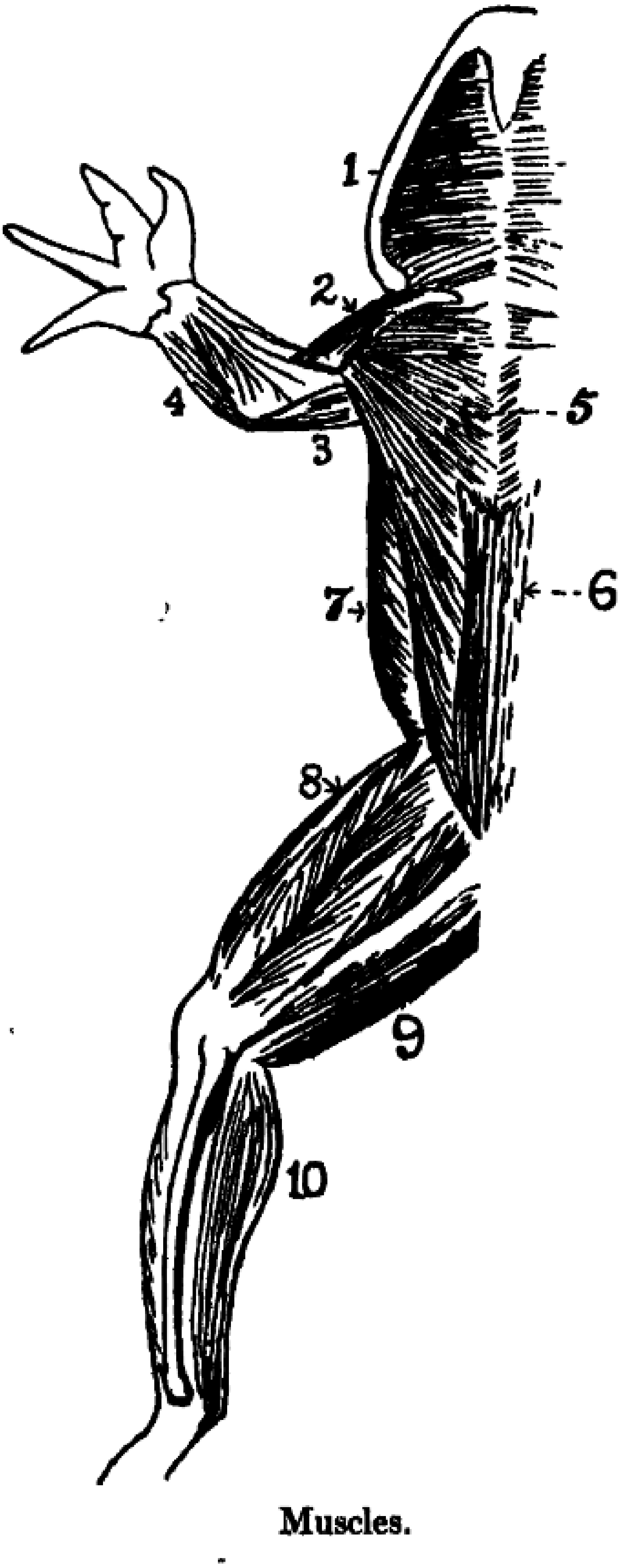
Just below the skin, a series of large spaces are found called subcutaneous lymph-sacs. The flesh below the sacs is bound to the skin by connective tissue. Owing to the presence of sacs the skin is much looser than most other animals. The flesh is composed of muscles. Therefore a body-wall is found composed of skin and muscles. There is a lining membrane of the body-wall known generally as Peritoneum. This wall encloses a large cavity of the body found in the trunk called the Body-cavity or **Coelome,** in which lie most of the principal viscera. The term **viscera** denotes the soft internal organs of the body *viz.*, the Stomach, Lungs, Heart, Intestine, Liver etc., and the generative and execretory organs.

The animal has a backbone on the dorsal part called the **Vertebral column,** composed of a number of vertebræ. The vertebral column has a continuous cavity in which the **spinal cord** is placed. The spinal cord is continued into the skull and ends in the Brain lodged inside the **cranium.**

There are two bony girdles *e.g.,* the **Shoulder girdle** and the **Pelvic girdle.** The girdles together with the vertebræ completely encircle the body. The shoulder girdle gives attachment to the hind limb. The muscles of the limbs are supported by bony structures. The Cœlome is lined by a membrane called **Peritoneum** which also covers the organs lying in the cavity as viscera so that the organs lie within the folds of the Peritoneum and the organs are attached to the body-wall by such membranous folds. The largest fold is known as the **Mesentery** which binds the intestine to the Cœlomic wall. There are two dorsal lymph-sacs between the peritoneum and the dorsal muscles. Each of the two kidneys lies in the dorsal lymph-sac of each side.

Muscular System :

The muscles carry out the movements of the body with the help of the nerves which give them the requisite sensitiveness and action. The muscles of the limb and other parts are of the Voluntary type *i.e.,* they are under the control of the will whereas the muscles found in the Stomach, Heart, Intestine etc. are involuntary, *i.e.* they are not under the control of the will. All the muscles are covered by a structure called Fascia which is mainly composed of connective tissue. The details of the muscles are not meant for Intermediate students. (The principal



Muscles.

1—Mylo-hyoid, 2—Deltoid, 3—Latissimusdorsi, 4—Infraspinatus, 5—Pectoralis, 6—Rectusabdominis, 7—Obliquusexternus, 8—Vastusinternus, 9—Gracilis, 10—Gastrocnemius.

muscles of the body of the toad are distributed as follows :—

(1) Muscles of the Trunk. Ventral side.

Abdominal Muscles :

- (*a*) Rectus abdominis-runs along the belly.
- (*b*) Obliques Externus—a broad sheet at each side of the body.
- (*c*) Obliques Internus and Transversus lie within the External oblique.

Breast Muscles :

- (*a*) Pectoralis—large and fan-shaped.
- (*b*) Coraco-radialis—arising from the coracoid.

Muscles of the Back :

- (*a*) Muscles of the Lower jaw.
  - (1) Depressor Mandibular arising from the supra-scapula.
- (*b*) Muscles inserted on to the forelimb.
  - (1) Latissimus Dorsi—triangular. It draws back the arm. It is inserted into the Deltoid ridge.
  - (2) Infraspinatus—raises the arm.
- (*c*) Muscles inserted into the shoulder girdle.
  - (1) Levator scapular—
  - (2) Serratus—
- (*d*) Muscles inserted into the hind limb.
  - (1) Gluteus—arising from Ilium.

- (*e*) Muscles inserted into the Hipgirdle.
  - (1) Coccygeo—iliacus.

Muscles of the Back bone :-

- (*a*) Muscles of the forelimb.
  - (1) Muscles for the upper arm. Deltoideus inserted to the Humerus.
  - (2) Muscles for the forearm Triceps Brachii arising from the scapula and Humerus, and inserted into the upper end of Ulna.

Muscles of the Hind limb :

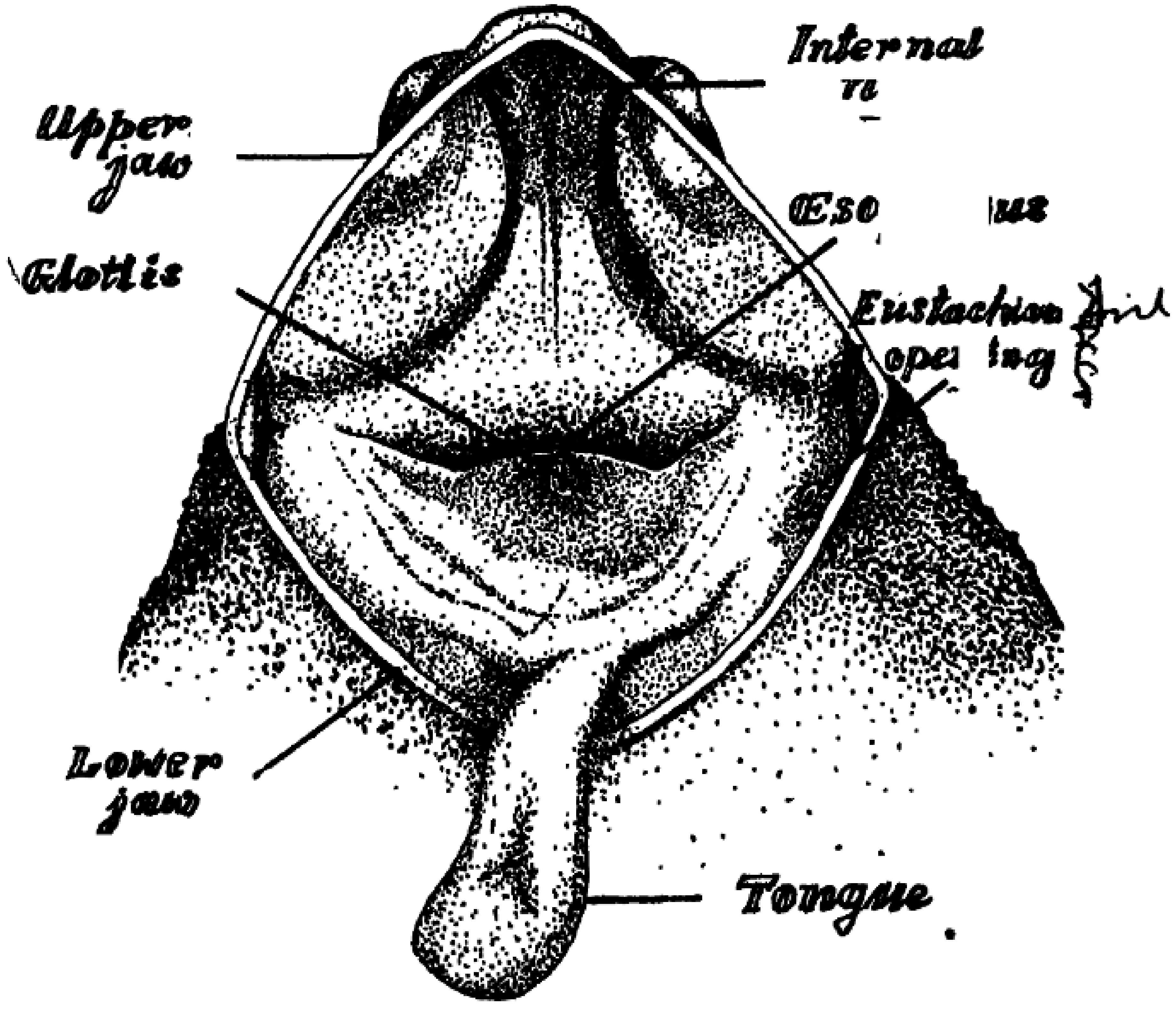
- (*a*) Muscles of the thigh.
  - (1) Adductor Magnus.
  - (2) Sartorius.
  - (3) Gracilis.
  - (4) Triceps Extensor Cruris.
- (*b*) Muscles of the Shank.
  - (1) Peroneus.
  - (2) Gastrocnemius.
  - (3) Tibialis Anterior.
- (*c*) Muscles of the wrist, ankle and toes are numerous small muscles.

Alimentary System :

There is a large mouth with upper and lower jaws. The jaws are toothless but the upper part of the jaws become hard and horny and do not allow the prey to slip away as the toad lives on small insects.

The mouth leads into the Buccal cavity where the tongue is attached in front but free behind. The tongue is rolled out to catch insects and a sticky secretion helps to hold them.

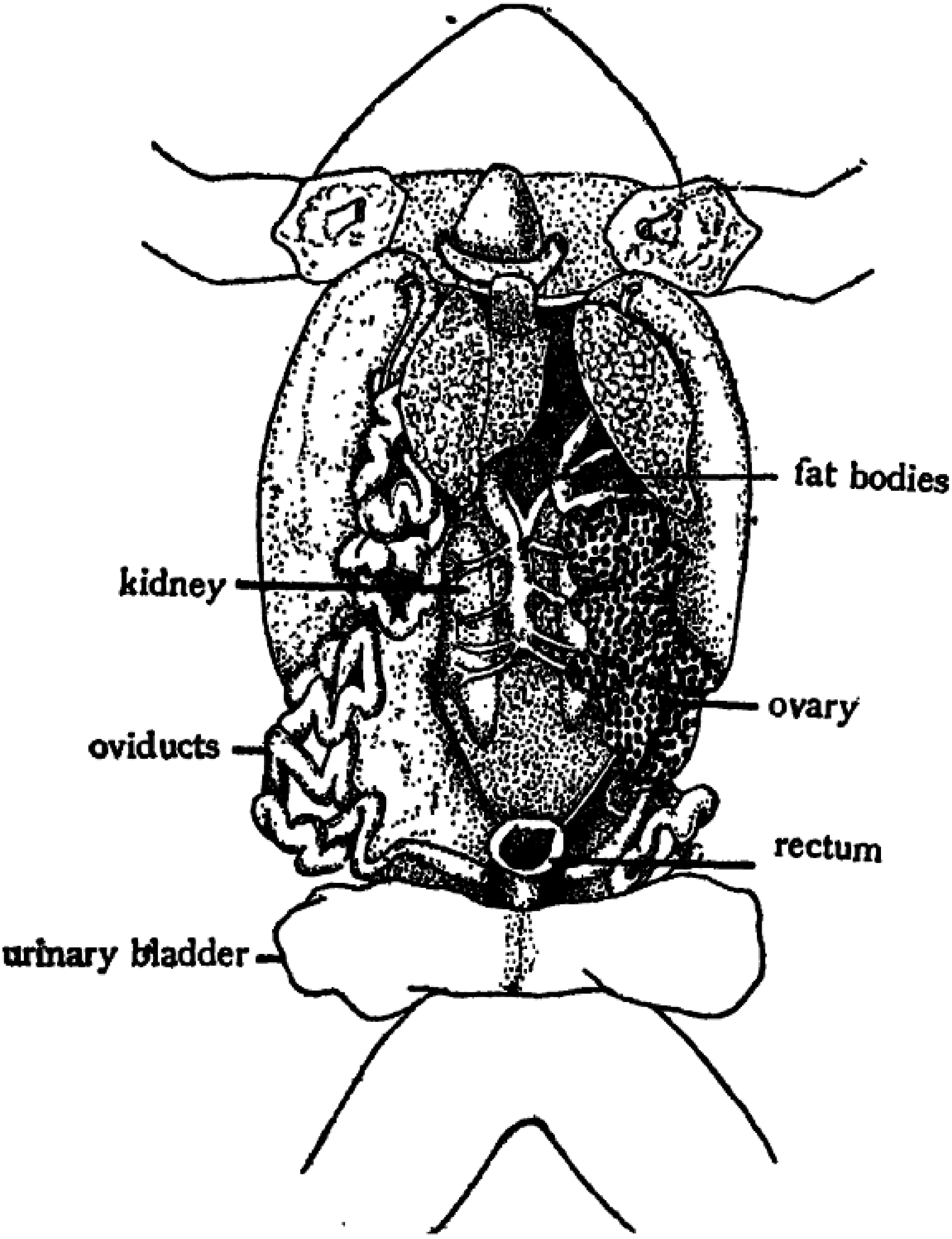
The floor of the mouth specially on the right side shows an aperture. This is the opening of the Vocal-sac found in the male animals only. When the chin is depressed the vocal-sac is filled with air and when it is raised air escapes and produces the peculiar croaking sound which is heard more frequently in the breeding



Buccal cavity

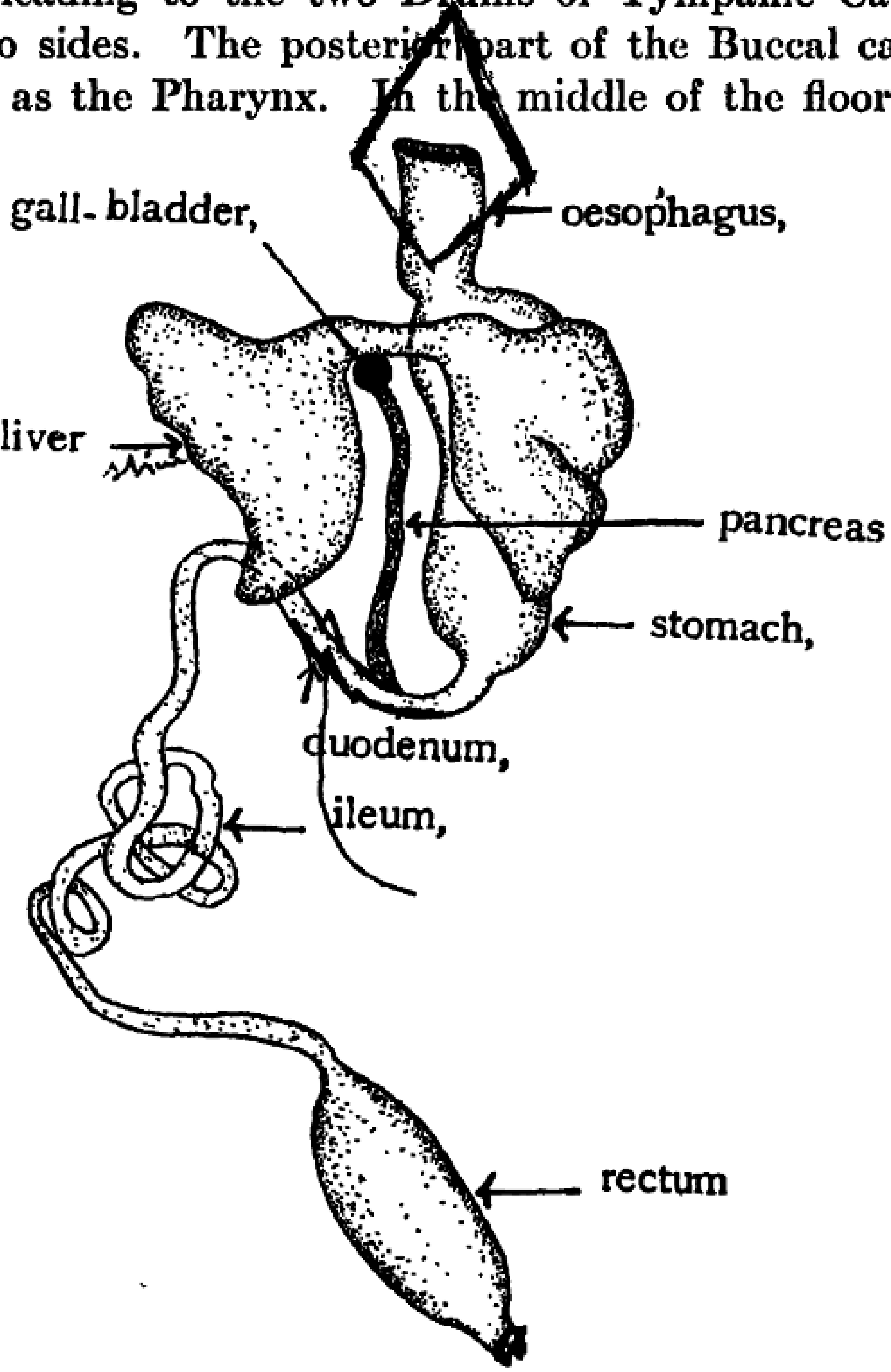
season and during the rains by which sound the male trumpets the female.

On the roof of the Buccal cavity in the front part there are two apertures of the **posterior nares** or Internal Nostrils. At the angle of the jaws on the sides of the roof there are two other apertures of the **Eustachian**



Viscera of toad

tubes leading to the two Drums or Tympanic Cavity of the two sides. The posterior part of the Buccal cavity is known as the Pharynx. In the middle of the floor of the



Gut of toad with glands

Pharynx is a slit-like opening which leads into the Windpipe. From the Pharnyx a tube which is called **Gullet** or **Oesophagus** leads backwards to the stomach which is spindle like in form. The stomach has two ends. The end which is anterior and is connected with the Oesophagus is known as the **Cardiac end.** This end is wider than the other end. The other end of stomach is called the **Pyloric end** and is connected with intestine.

The intestine is divided into two main divisions *viz.*, the **small intestine** and the **large Intestine.** The small intestine has further two parts *e.g.* a short straight tube called the **Duodenum** and a much coiled tube called the **Ileum.** The Ileum leads into the dilated and short Large Intestine or **Rectum.** The Rectum opens into a chamber called **Cloaca** by an aperture called the **Anus.** The **Cloaca** in its turn opens externally by the **Cloacal aperture.** The intestine is kept/bound to the wall of the abdomen by a fold of Peritoneum called the Mesentery.

Digestive Glands :

Besides the digestive fluids secreted by the glandular cells of the Stomach and Intestine there are glands the secretion from which completes the digestion. The glands are the **Liver** and the **Pancreas.** The Liver is a large reddish brown structure in the front part of the stomach. It has two main lobes *viz.*, right and left and a small median lobe unites them. The **Gallbladder** lies between the right and left lobes. The Gallbladder receives the green **bile** secreted by the Liver and passes it by the Bile Duct into the Duodeum.

The Pancreas is a creamy white structure lying between the stomach and the Duodenum. It is traversed by the Bile Duct into which it pours forth its own secretion called the Pancreatic juice.

The ducts of the Liver are called **Hepatic Ducts.** The duct from the Gall Bladder is called the **Cystic Duct** and that from the Pancreas is called the **Pancreatic Duct.** Both the Cystic Duct and the Pancreatic Duct open into the Duodenum by a common Bile Duct.

Endocrine Organs or Ductless Glands:

There are certain glands in the body of the toad which do not discharge their secretions directly by definite tubes or Ducts but they pour their secretions direct into the blood whereby they can control certain chemical and physiological actions of the body. These are known as Endocrine organs or Ductless glands. They are :—(1) Thyroid,

(2) Supra-renals or Adrenals,

(3) Thymus.

(4) Pituitary.

(5) Spleen.

The **Thyroid glands** are a pair of round bodies lying on the external Jugular veins. The change from tadpole to the adult toad is brought about by it. **The Adrenal** bodies lie on the ventral surface of the kidneys.

The Thymus is a small body lying behind the angle of the jaw. Its functions are unknown.

The Pituitary body lies in the skull below the Brain. Its secretion stimulates the growth of the animal and the growth of bones. *Certain chemical agents* are secreted by these endocrine glands called **Hormones** which stimulate or inhibit the function of other **organs** of the body.

The **spleen** lies in the Mesentery of the Abdomen. Its cells remove and destroy effete red blood corpuscles and pathogenic organisms. Its removal is not fatal.

Fat bodies :

The **fat bodies** are found anteriorly to the Reproductive Organs of the toad They increase in summer and are used in winter mostly as nourishment.

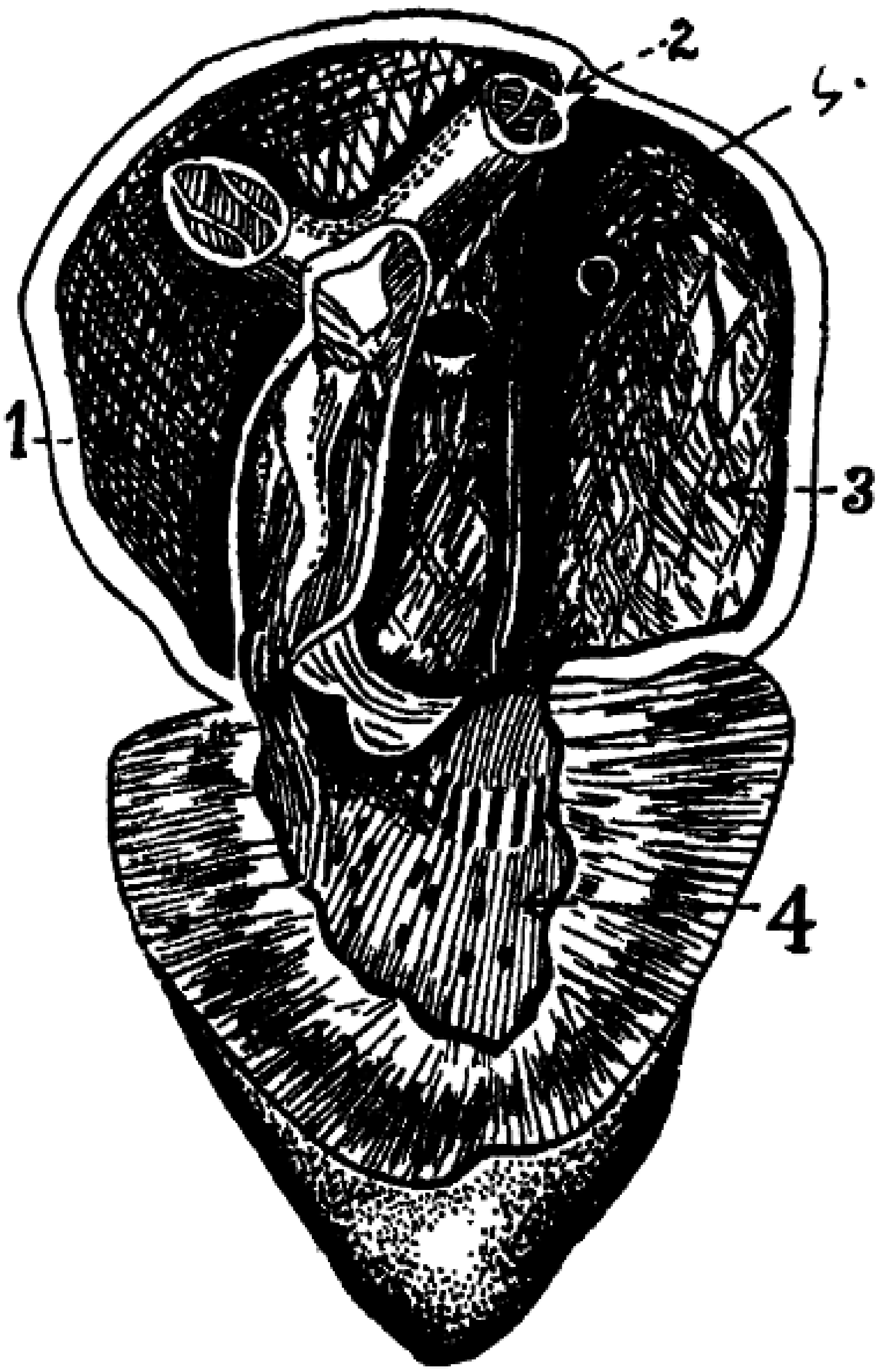
The Heart and Circulatory System.

(The description of the Heart and the Circulatory System has been done according to Mr. J. L. Bhaduri's excellent paper published in the Journal of the Asiatic Society of Bengal).

The Heart of Toad is a hollow organ covered by a membranous sac called the **Pericardium.** The Heart has a triangular portion at the back called the **Sinus Venosus** into which the principal veins of the body open. There are **two auricles right and left and a single Ventricle** which gives rise to the main Blood vessels. The Apex of the Heart is directed backwards into the body cavity. The different chambers of the Heart are guarded by valves so that blood can flow in one direction only. The Heart, therefore, has the following structures :

(1) The **Sinus Venosus.**
(2) **Right Auricle.**
(3) **Left Auricle.**
(4) **Single Ventricle** and
(5) **Conus Arteriosus.**

The Sinus Venosus is a triangular chamber into which the principal veins of the body open *viz.*, Two anterior veins and a single posterior vein. The Sinus Venosus opens into the right auricle by an aperture called sino-auricular aperture guarded by two flap-like valves. The blood is allowed to pass from the Sinus Venosus to the Right Auricle but not in the opposite direction owing to the presence of valves. The Right Auricle is a thin-walled sac separated by a partition from the Left

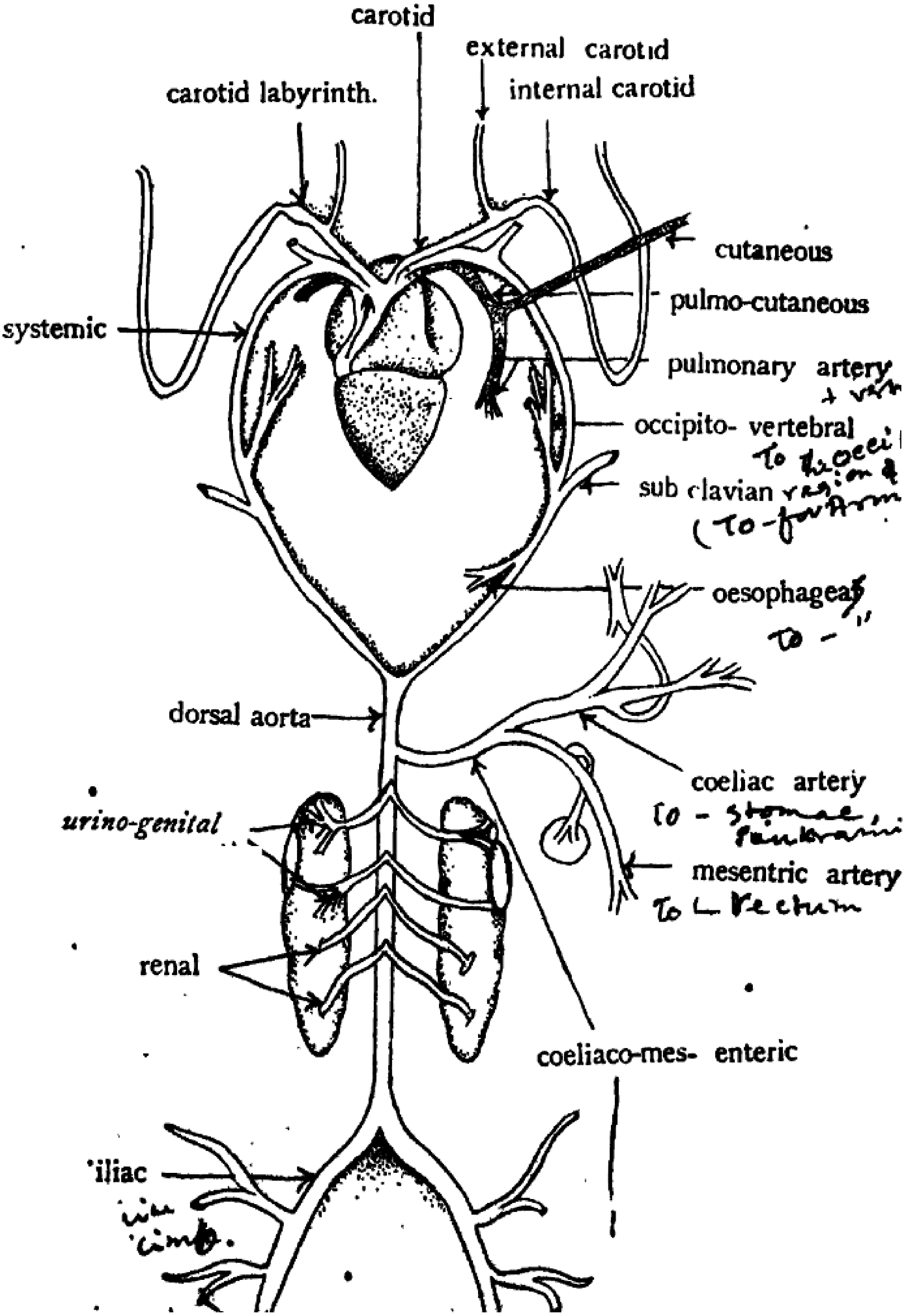


Section of Heart.
1—Right auricle, 2—Truncus arteriosus sinister, 3—Left auricle, 4—Ventricle.

Auricle called the **Septum Auricularum.** The Right Auricle receives the blood from the Sinus Venosus and communicates with the Ventricle by the Auriculo-ventricular aperture which is guarded by Valves. The Left Auricle is situated on the left side being smaller in size than the Right Auricle. It receives pure oxygenated blood coming from the two Lungs by the two Pulmonary veins which open together by a common aperture. The Left Auricle communicates with the Ventricle by the common Auriculoventricular aperture guarded by valves. The valves are attached to the wall of the ventricle by fibrous cords called Chordæ tendinæ. The valves allow the blood to pass from the Left Auricle to the Ventricle and not in the opposite direction. There are four valves guarding the auriculoventricular aperture between the two auricles and the ventricle. There is one anterior, one posterior and two lateral valves.

The Ventricle is a thickwalled conical organ having strong muscular walls. It is a single chamber where the two auricles open and the openings are guarded by Auriclo-ventricular valves. A large blood vessel rises from the right side of the Ventricle and is known as the Conus Arteriosus. The opening of it is guarded by three semilunar valves which allow the blood to move from the Ventricle to the Conus and not otherwise.

The Conus Arteriosus arises from the right side of the Ventricle Its basal portion is called Conus proper which is continued into a short common portion called **Truncus Arteriosus impar.** This divides into two trunks called **Truncus arteriosus dexter** on the right side and **Truncus Arteriosus Sinister** on the left side. The two trunks have three vessels in each which run for a distance enclosed by a common sheath. Each trunk is divided internally by two partitions to form the **Canalis**


carotid
external carotid
carotid labyrinth.
internal carotid
cutaneous
pulmo-cutaneous
systemic
pulmonary artery
+ ver
occipito- vertebral
To the occi region &
sub clavian
(To-forArm
oesophageal
To - ''
dorsal aorta
coeliac artery
To - stomach, pancreas
urino-genital
mesentric artery
To L Rectum
renal
coeliaco-mes- enteric
iliac
via limb.

Caroticus, the **Canalis Aorticus** and the **Canalis Pulmocutaneous.** The three vessels run in a common sheath for a short distance and then the three arterial arches are separated on each side forming the **Carotid arch,** the **Systemic arch** and the **Pulmocutaneous arch**

Arterial System :

The Conus Arteriosus is continued into Truncus Arteriosus Impar which bifurcates into Truncus Arteriosus Dexter (Right) and Trunctus Arteriosus Sinister (Left). Each trunk carries the three canalicular vessels in a common sheath which form the three arches called Carotid Arch, the Systemic arch and the Pulmocutaneous arch.

Carotid Arch :

The Carotid arch is the anterior one and supplies the head and brain. The Carotid arch shortly after its origin forms a swelling called the Carotid Labyrinth or 'Carotid Gland.' The arch gives off a branch near the Carotid gland called the External Carotid Artery which gives a branch to the thyroid, the hyoid apparatus and its main trunk supplies the tongue. The other main branch is known as the Internal Carotid Artery. It runs superficially for a distance and then takes a sharp turn to enter into the skull where it supplies the Brain.

Systemic Arches :

The **Systemic arch** or **Aortic arch** is the median arch of each side. Each arises from the Cannalis Aorticus and winds obliquely round the œsophagus and then turns inwards and backwards to join its fellow from the opposite side at about the level of the sixth vertebra. The right systemic arch is continued as the Dorsal Aorta in the middle line just ventral to the vertebral column and between the Kidneys to about the middle of the urostyle where it bifurcates into two **Iliac** arteries. The left Systemic arch after its union with the right arch continues as the Cœliaco-mesenteric artery. The right systemic arch gives out three branches while the left systemic arch gives out four branches. The right arch having no œsophageal branch. The branches of the Systemic arches are :—

(1) **Laryngeal** artery arising from the inner border of the systemic arch supplies the Larynx and its muscles.

(2) **Occipito-vertebral** artery arises near the subclavian artery and runs forwards to divide dorsally into the occipital and the vertebral arteries.

(3) **Subclavian artery** the largest branch arising from the Systemic arch. It supplies the Pectoral girdle and the forelimb.

(4) **Oesophageal artery** is present only in the left systemic arch. It supplies the œsophagus.

The **Coeliaco-mesenteric** artery arises by a single trunk from the point of union of the two systemic arches, and supplies the alimentary canal and its various appendages. It divides into two main branches (1) **Coeliac artery** and (2) a **Mesenteric artery.**

The Cœliac artery is small. It supplies the stomach, Liver, Gall-bladder and the Pancreas.

The Mesenteric artery is a large branch which supplies the spleen, the whole intestine and the rectum.

Dorsal Aorta :

The Dorsal Aorta is continued through the whole of the abdomen. The urino-genital arteries aries as paired arteries from the Dorsal Aorta. About four paired arteries called the renal arteries supply the kidneys, the fat bodies and two genitals supply the reproductive organs.

Lumbar arteries are absent in the toad.

Posterior Messenteric artery is also absent in the toad.

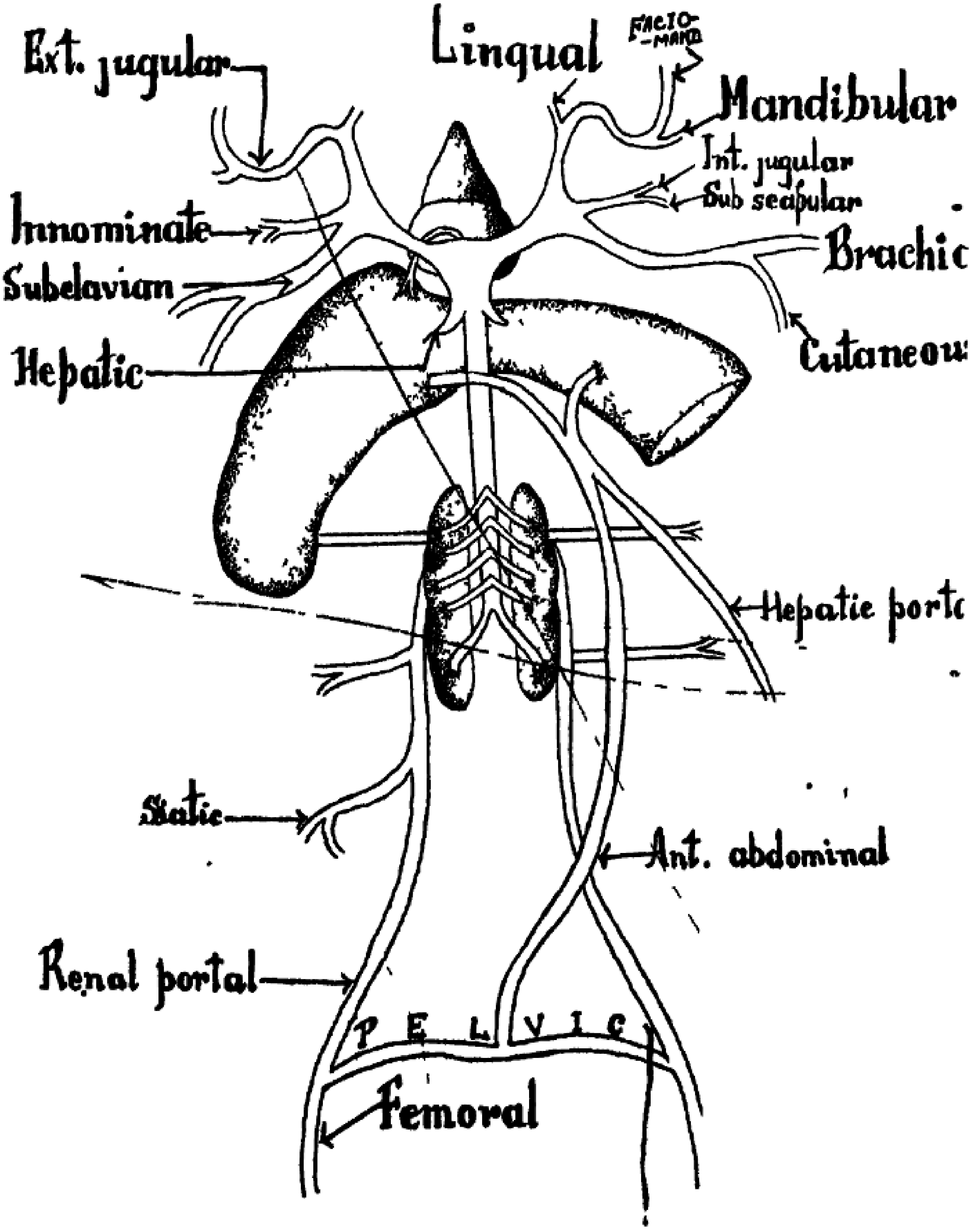
Iliac Arteries are the ultimate bifurcations of the Dorsal Aorta near the urostyle. The Iliac artery is continued to the thigh as the **Sciatic** artery. Before reaching the thigh the Iliac artery gives off two important branches *viz.*, the Epigastricovescicalis artery which supplies the bladder and its adjoining muscles, and the **Femoral** artery which supplies the muscles of the thigh The rest of the hind limb is supplied by the Sciatic artery.

Pulmo-Cutaneous Arch :

The hindmost of the three arches is the **Pulmo-cutaneous** arch. It passes to the Lung as **Pulmonary artery** on each side where it ramifies by a number of branches. Before entering the Lung a fine branch is given off to the skin as Cutaneous artery. On entering the skin it branches and forms several anastomoses.

Venous System :

There are two kinds of veins in the toad, viz., the systemic veins and the Portal veins. The systemic veins bring blood directly to the Heart whereas the Portal veins break down into capillaries into an intemediate organ or organs before opening into the Heart.



Systemic Veins :

Blood which is distinctly visible through the veins which are comparatively thin-walled than the arteries and due to the presence of pigments in the venous blood comes from the front part of the Toad's body by two principal veins called the **Anterior Venae Cavae** or **Superior Venae Cavae.** Each Anterior Vena Cava opens into the Sinus Venosus. It is formed by the union of three veins viz.,

(1) **External Jugular** vein which is formed by
  (*a*) The **lingual** vein from the floor of the mouth and tongue.
  (*b*) The **Facio-Mandibular** vein from the margin of the lower jaw.

(2) The **Innominate** Vein which is formed by
  (*a*) Internal Jugular vein returning blood from the interior of the skull.
  (*b*) **Subscapular** vein from the back of the arm and shoulder.

(3) The **Subclavian** vein, the largest of the three, which is formed by
  (*a*) **Brachial** vein from the forelimb.
  (*b*) The **Musculo-cutaneous** vein returning blood from the skin and muscles of the side and back of the body.

The Right and the Left Anterior Vena Cava are similar in their course and distribution.

The **Posterior Vena Cava** is a single median vein bringing blood from the lower part of the body. It begins between the Kidneys and runs forwards and receives blood from the Liver and opens into the Sinus Venosus. The veins which the Posterior Vena Cava receives are :—

(1) Four pairs of Renal veins from the two Kidneys.

(2) Genital veins, called ovarian in the female and Spermatic in the male, also open with the Renal veins into the Posterior Vena Cava.

(3) Right and Left Hepatic veins open into the Posterior Vena Cava just before it joins the Sinus Venosus.

The **Pulmonary Vein** is formed by the union of two Pulmonary veins bringing blood from the two Lungs after oxygenation. This vein opens into the Left Auricle.

Portal System :

There are two portal systems in Toad viz.,

(1) **Renal portal system** and

(2) **Hepatic portal system.**

There is a stout vein bringing blood from each leg called femoral vein. The Femoral divides on leaving the thigh into two veins of which one goes to the ventral part and is called **Pelvic vein** which joins with its fellow of the other side. The other vein is called the Renal portal vein which passes to the dorsal part of the Kidney and breaks up into capillaries in its substance and then by renal veins the blood passes into the Porterior Vena

Cava. The Left and the right Renal portal veins are similar. Each Renal portal vein receives :—

(*a*) The sciatic vein from the muscles and skin of the thigh

(*b*) The Dorso-lumbar veins receive blood from the dorsal wall of the body. They join the Renal portal vein opposite the Kidney.

The Hepatic Portal System :

This system is formed partly by the Anterior Abdominal vein and partly by the veins of the Alimentary canal. The Anterior Abdominal vein is formed by the union of the two pelvic veins which runs just along the middle line of the body wall ventrally. Near the Liver it divides into two veins passing into the two lobes of the Liver. It receives the following veins in its course :—

(*a*) The **Vesical** veins from the bladder.

(*b*) The **Parietal** veins from the ventral body-wall.

The Hepatic portal vein receives the following veins from the Alimentary canal : —

(*a*) The **Gastric veins** from Stomach.

(*b*) The **Intestinal veins** from the intestines both small and large.

(*c*) The **Splenic vein** from the Spleen.

Blood :

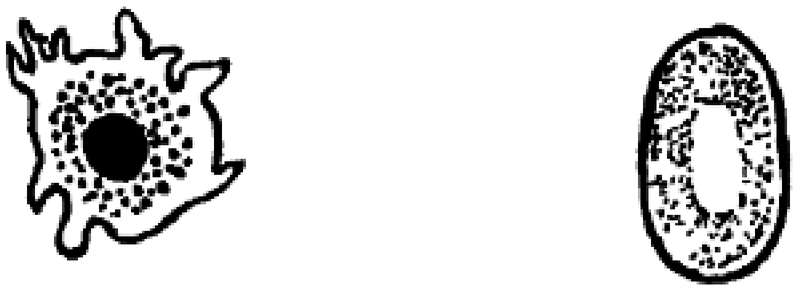
The blood of Toad consists of a colourless fluid called the Liquor Sanguinis or **Plasma** in which float the blood corpuscles. The corpuscles are of two kinds viz :—

(1) **White Blood corpuscles** or **Leucocytes,** which are nucleated and amœboid.

(2) **Red Blood corpuscles** which are oval and also nucleated but not amœboid.

Circulation :

The impure or venous blood is brought to the Sinus Venosus by three Venæ Cavæ. Blood is prevented from going back on account of the presence of valves at the junction of the principal veins. The Sinus Venosus opens into the Right auricle. Pure blood comes to the Left auricle from the Lungs by the Pulmonary veins. When the two auricles contract one after another, blood passes into the ventricle. The venous blood first comes to the ventricle. When the ventricle contracts the venous blood passes into the Pulmocutaneous arch and then into the Lungs for purification because there is the least resistance in these arches. With the second contraction of the Ventricle blood passes into the systemic arches and is distributed to the different parts of the body. But this blood is to some extent mixed blood. The third contraction gives the most vigorous jerk and forces the blood to enter into the Carotid arches where the greatest resistance is offered by the Carotid gland. The Carotid arch receives the pure blood. The Carotid and Systemic arches distribute the blood to the different parts of the body where ultimately the arteries break down into capillaries. The impure blood from the tissues of the



White and red blood corpuscles

body is brought to the Heart by the Veins. This cycle is ever repeated as long as the animal lives.

There is another form of circulation through the skin. Blood comes to the skin by the Cutaneous artery where it is oxygenated specially while the animal is hibernating. The pure blood passes by the Musculo-cutaneous vein into the Anterior Vena Cava and thence returns to the Heart. Blood from the lower part of the body comes either by the Renal Portal System or through the Hepatic Portal System. This blood ultimately comes to the Posterior Vena Cava, and then to the Heart.

Lymphatic System :

This consists of a system of minute vessels and irregular spaces in the body containing a colourless fluid called the Lymph. The Lymph has a number of colourless corpuscles called Lymphcells or Lymphocytes. The Lymph spaces occur in the ventral body-wall below the skin. There are two pairs of Lymph Hearts, one pair below the supra-scapula and the other pair near the Urostyle.

Respiratory System :

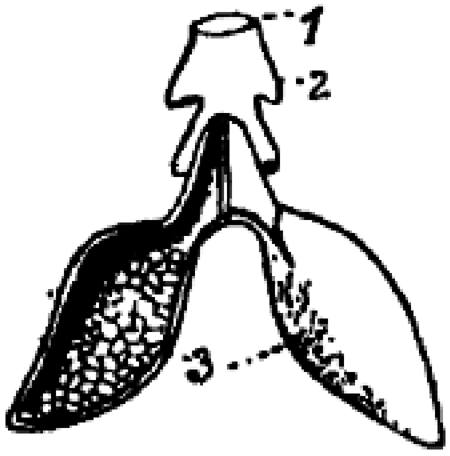
There is an aperture at the floor of the Pharynx which is known as the **Glottis.** This Glottis leads into a chamber which is known as **Laryngo-tracheal chamber** which corresponds to the Larynx and Trachea of the Mammals. The walls of the chamber are made of cartilages. The chamber opens into the two Lungs. The Lungs are composed of Elastic fibres, connective tissue and unstriped muscles. They are lined with pavement epithelium on the inner side, while the outer surface is covered with the pleural membrane.

Air on entering through the nostrils finds its way into the Buccal cavity when the floor of the mouth is raised by the Hyoid muscles and the gullet remains closed in a contracted condition. The mouth is closed except during swallowing whereby air enters by one way only due to the pressure of the muscles. The air then passes into the Lungs. This is called Inspiration which is helped by the suction action exerted by the inflation of the Lungs. This incoming air contains oxygen which supplies the blood contained in the capillaries of the Lungs. The other process which is called expiration is due to the elastic recoil and contraction of the Lungs, whereby the air is driven out. This expelled air contains CO_2 derived from the venous blood. Thus by inspiration the blood in the lungs is oxygenated and by expiration CO_2 is got rid of.

1—Glottis,

2—Laryngotracheal chamber,

3—Lungs.



Voice :

The Glottis and the Laryngo-tracheal chamber are supported by cartilages. The largest pair of cartilage is the Arytenoid which bound the Glottis right and left. The mucous membrane of the Arytenoids is raised into the vocal cords the vibration of which produces the peculiar croaking sound of the Toad.

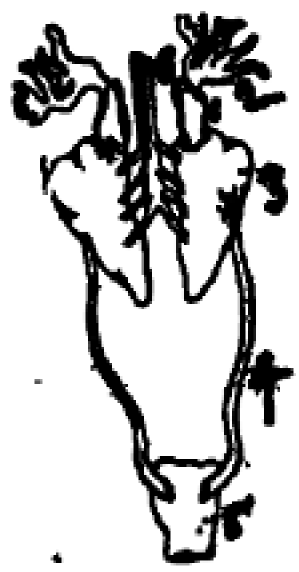
The Excretory System :

There is a pair of flattened dark red kidneys one on each side in the dorsal lymph sac above the Cœlome and just below the back bone or Vertebral column. Waste products of the body in the form of CO_2 and water vapour pass out of the system through the Lungs but the other waste products in the form of urea, uric acid and other solid crystalloids circulating in the blood are got rid of through the kidneys dissolved in water as urine. The kidneys therefore act as filters of waste materials of the blood. Each kidney consists of a number of tubules. Each tubule begins as a blind sac called the Glomerulus and after making several coils joins with the other tubules and finally emerges out of the kidney as ureter. The ureter carries the urine to the Cloaca from which it might be voided immediately or it may be collected in a sac called the Urinary Bladder. Glomeruli receive blood from the Renal artery and the tubules from the Renal Portal vein.

Reproductive System :

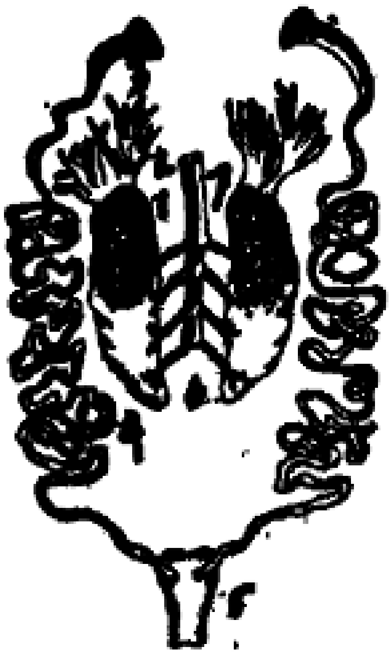
The animals have separate sexes *i.e.* they are either male or female.

Male.



1—Testis,
2—Fatbody,
3—Kidney,
4—Ureter,
5—Cloaca,
6—Posterieor vena cava.

Female.



1—Ovary,
2—Fatbody,
3—Oviduct,
4—Oviduct,
5—Cloaca,
6—Kidney,
7—P. V. C.

Male :

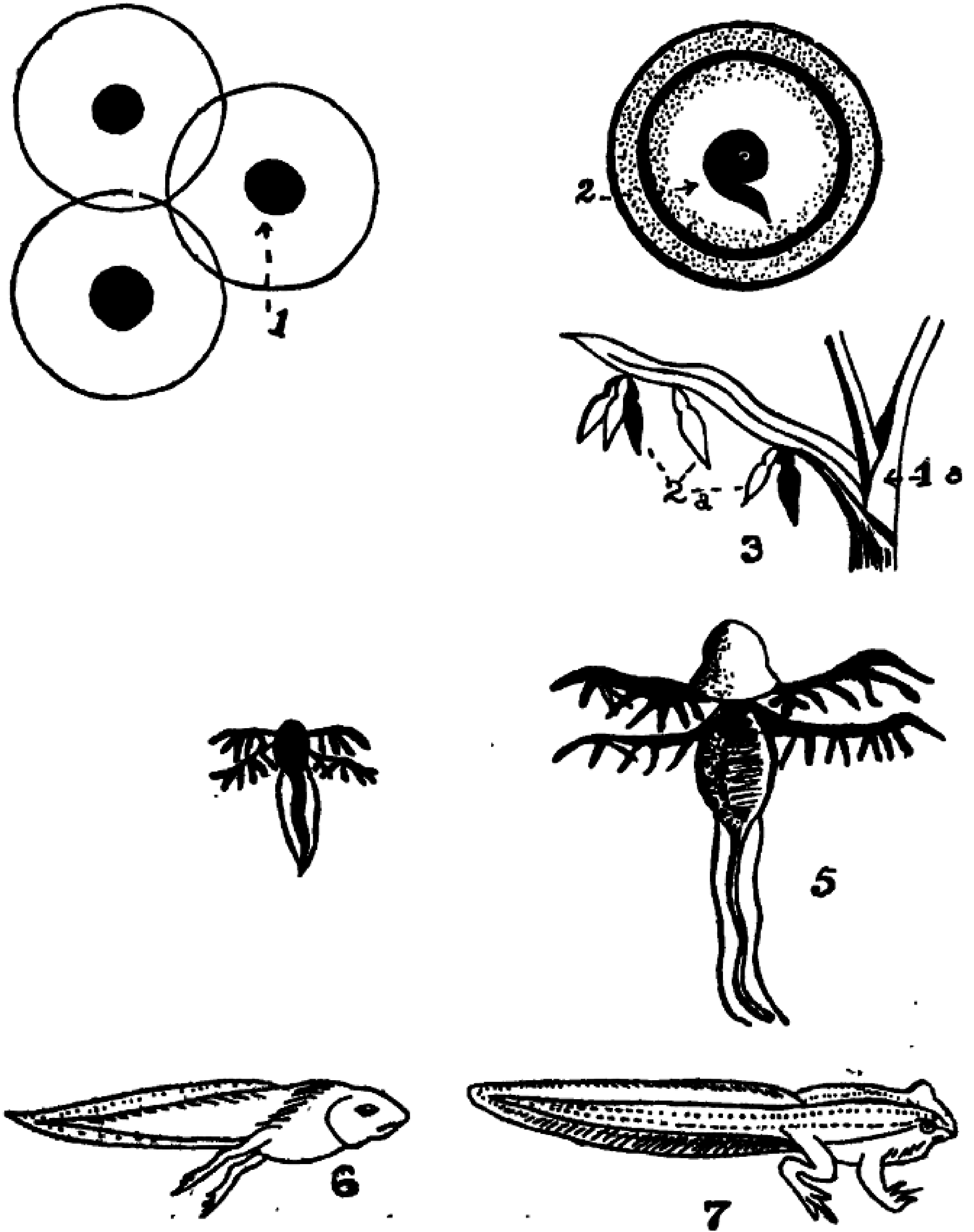
The organ in which the male elements are formed is known as **Testis.** There are two testes on the ventral side of the kidneys. They are ovoid bodies and yellow in colour. Each testis has a fat body in the anterior part. The testes are composed of seminiferous tubules which produce the male cells or spermatozoa. Each sperm has a nuclear head and a long tail. The sperms pass out of of the testes by a number of ducts into the tubules of the kidney. The ducts are called Vasa Efferentia. From the kidney the sperms are taken away by the ureter to the Cloaca. Here the Ureter also acts as the Vas Deferens and is known as the Woolffian Duct. The two ducts join before finally opening into the cloaca.

Female :

The female generative organs consist of the two **ovaries.** The ovaries become very large during the breeding season on account of the development of numerous eggs therein. When the ovary is mature and the eggs are ripe there is a bursting of the wall of the ovary and the eggs called ova are discharged into the abdominal cavity. Each ovum makes its way into the **Oviduct** which is a much coiled tube and passes thence into the water where they are fertilized by the male elements called Spermatozoa.

Metamorphosis of Toad :

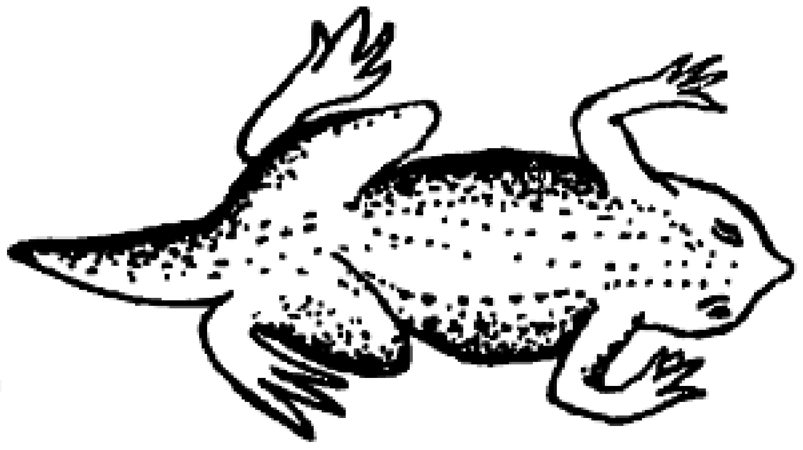
The female Toad lays the eggs in a mass called the spawn. Each egg has a jelly-like covering by which the eggs are attached to one another to form a mass. Each egg is round and contains a large nucleus. The male toad sheds off the sperm cells (male elements) near the spawn and fertilisation takes place in water. A single



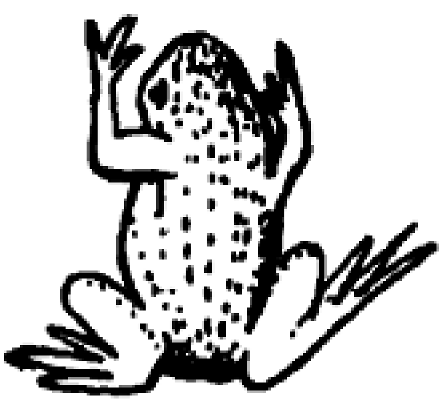
Metamorphosis of Toad
Read 3 pairs of gills in figs. 4 and 5.
1a—Aquatic weed, 2a—Tadpole.

male cell combines with a single female cell and result in the development of a tadpole. The fertilised egg separates out of the spawn and undergoes development. Mortality is great among these fertilised eggs because the toads do not nurse their young ones in any way. So that the majority of them are either eaten up or destroyed by other aquatic animals.

The Embryo at first has a large head, a long tail but no limbs. The Larva is at first very sluggish and does not take any food but attaches itself to some water weed by means of a sucker on the under surface of its head. Later on the Tadpole becomes active and swims about in water. On both sides of the head appear three branched gills for respiration. At first there is no connection between the mouth and the alimentary tube but there is a cloaca. The mouth later on becomes connected with the food canal and the intestine is seen like a watch-spring and is a much coiled tube. The long size of the intestine is due to the vegetable diet which necessitates a comparatively large size of the gut. The gills at a subsequent period degenerate and are replaced by internal gills arising from the Branchial arches. They are covered by a fold of skin called Operculum.



8



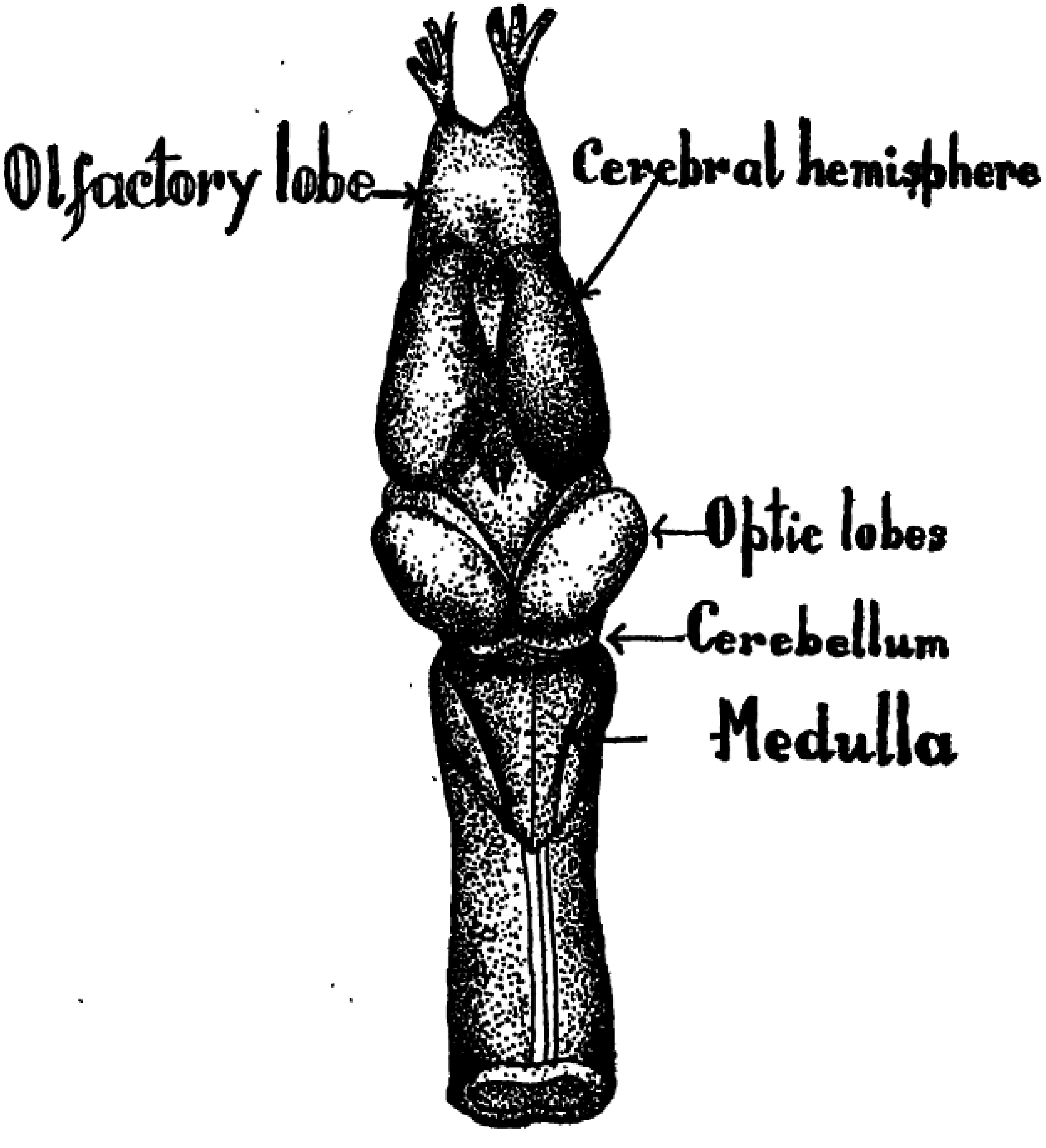
9

1 to 9 represent the stages of development,

The Tadpole at this stage seems to have a fish-like life. The Operculum later on closes and there is left only a single aperture on the left side through which the current of water passes out. Subsequently Lungs appear and the gills are lost. The Tadpole periodically rises to the surface of water for oxygen. The limbs at this time begin to appear, one pair as slight projection at the root of the tail and another pair just below the head. The tail gradually atrophies but the most peculiar phenomenon noticed is that the tail supplies nourishment to the Embryo at this stage until ultimately the tail is lost and the legs are fully developed. The adult toad gives up its vegetable diet and hops about on land in search of insects which forms the main animal food of the full grown animal.

Brain :

The Brain of Toad is divided developmentally into three regions as the fore-brain, mid-brain and hind-brain. The fore-brain gives rise to two cerebral hemispheres and the thalamencephalon. The thalamencephalon lies just in front of the mid-brain. The thalamencephalon bears on the ventral side a body called the hypophysis or Pituitary Body. This Pituitary body is composed of non-nervous matter. On the dorsal side the thalamencephalon bears a body called the Pineal body. In the Tadpole stage this is stalked and represents the remnant of the third eye. Ventrally the thalamencephalon shows a hollow structure called the Infundibulum. The cerebral hemispheres bear the two olfactory lobes in front. The mid-brain lies in front of the cerebellum and medulla oblongata. It consists of the two optic lobes. The hind-brain is continued in the vertebral column as the Spinal Cord.



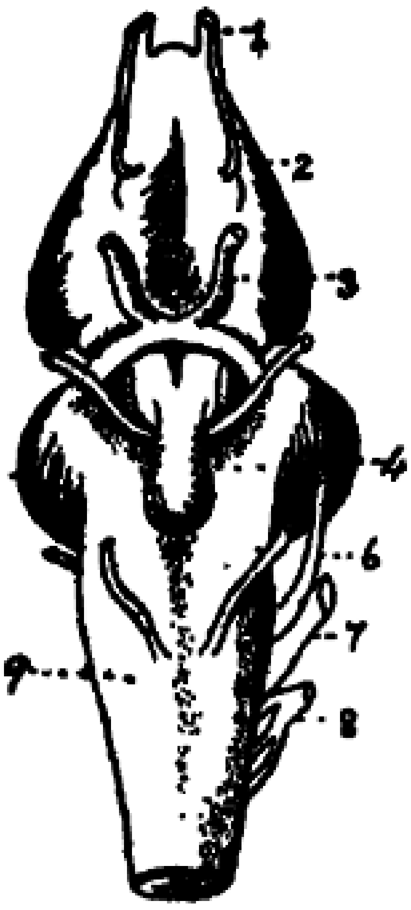
Brain of Toad

The Cerebellum is the narrow median portion just above the medulla oblongata.

On the ventral aspect of the brain the two optic nerves cross each other and the structure is known as the optic chiasma.

The different portions of the brain have cavities which are known as Ventricles. The cavity of the medulla oblongata is known as the Fourth Ventricle. There is a narrow passage between the optic lobes called the Aquiductus Cerebri which is continuous with the Fourth Ventricle. The cavity of the Thalamencephalon is known as the Third Ventricle. The cavity of the Cerebral hemispheres of each side is known as the Lateral Ventricle. Each lateral ventricle communicates with the Third Ventricle by the Foramen of Monro.

Ventral view of Brain



1—Olfactory lobe,
2—Cerebral hemisphere,
3—Optic nerve,
4—Pituitary,
5—Optic lobe,
9—Medulla oblongata.
6-8—Nerves.

Cranial Nerves :

There are ten pairs of cranial nerves in the Toad. The **Olfactory nerve** is the first cranial nerve of each side which rises from the Olfactory lobe of the Brain and supplies the olfactory organ in the nostril.

The second or **optic nerve** starts from the side of the mid-brain and crosses its fellow of the other side just below the thalamencephalon to supply the eyeball of the the opposite side. This crossing is known as optic chiasma and is seen on the ventral side only. The third or **oculomotor nerve** supplies the muscles of the eye. The fourth or **Pathetic** or **Trochlear nerve** arises between the optic lobes and the cerebellum. It supplies the superior oblique muscle of the eye. It is the only nerve which is found to rise from the drosal side of the Brain.

The fifth is known as the **Trigeminal nerve.** It arises from the anterior side of the medulla. It has a swelling in its course called the Gasserian Ganglion.

The fifth nerve divides into an Ophathalmic branch which runs in the orbit and supplies the skin of the head. The second branch is more prominent and goes to the hinder part of the orbit and divides into two branches called Maxillary branch to the upper jaw and Mandibular branch to the lower jaw.

The sixth nerve is small and is called the **Abducent nerve.** It arises from the ventral side of the medulla and supplies the external Rectus muscle of the eye.

The seventh or **facial nerve** arises from the side of the medulla and joins the **Gasserian Ganglion.** It then passes forwards and divides into Palatine branch which supplies the palate of the mouth and Hyomandibular branch which supplies the muscles of the Hyoid.

The Eighth or **Auditory** or **Acoustic nerve** rises also from the side of the medulla to supply the ear or Auditory apparatus.

The ninth or **Glossopharyngeal** arises also from the side of the medulla and proceeds towards the mouth.

It gives off a branch to the Hyomandibular nerve and others to the tongue and the mouth.

The tenth nerve is called the **Vagus nerve.** It supplies the important organs of the body. It has a ganglion at the base and is called the **Vagus Ganglion.** It then proceeds downwards and supplies the Larynx, Heart, Lung and Stomach.

The Sympathetic System :

The sympathetic system of nerves consists of two cords of nervous tissue lying by the side of the vertebral column. The spinal cord inside the vertebral column gives out numerous nerves called spinal nerves. The sympathetic cord is united to the spinal nerve by a Ramus Communicans. At the junction of each ramus communicans there is a ganglion of the sympathetic cord. The sympathetic cord passes to the skull and is connected with the tenth nerve and ends in the Gasserian Ganglion. The ganglia of the sympathetic cord give out small nerves to the viscera and blood vessels.

Sense Organs :

There are five principal senses *e.g.*, sight, hearing, smell, taste and touch. The senses are controlled by the Brain through the spinal cord and the nerves. The brain and spinal cord form the central nervous system while the sensory and motor nerves form the peripheral system.

Eye :

The eyeball of the toad consists of :—

(1) The outer coat or sense capsule. It consists of dense connective tissue with some cartilage and

is known as the sclerotic. In front it is transparent and is known as the Cornea.

(2) The cornea is covered over by a delicate transparent tissue called conjunctiva which is kept moist by the secretion of the Harderian glands.

(3) Inside the sclerotic or sense capsule is the choroid coat which consists of numerous highly vascular connective tissue with pigment cells. In front the choroid separates from the sclerotic as a partition screen and is known as the Iris across the hollow of the eyeball and divides it into anterior and posterior chambers. The former chamber, the anterior, is small and is filled with a liquid called the Aqueous Humour while the latter chamber, the posterior, is large and is filled with Vitreous Humour. There is a gap in the centre of the Iris which is called the Pupil.

(4) The Lens, a transparent biconcave or spherical body lies behind the Iris. It focusses light that comes through the pupil on to the Retina.

(5) The sensitive surface or coat of the eye is the Retina which receives the images of all objects that are seen. It consists of two primary layers of which the outer consists of pigmented cells and the inner layer is the Retina proper where the fibres of the optic nerve end after piercing it.

Ears :

The ear in toad has two parts *viz.*, the middle ear and the internal ear. There is no external ear like that of the mammals. The middle ear has got an outer membrane called the Tympanic membrane by which sounds are carried to the Internal Ear. The Internal Ear on each side communicates with the mouth by the eustachian tubes which open by apertures at the angles of the jaws. The cavity of the middle ear has a bone called the Columella Auris which is opposed to the tympanic membrane. The Columella is attached internally to a nodule of cartilage called the stapedial plate. The essential part of the Internal Ear is the membranous Labyrinth which consists of two sacs called the Utriculus and the Sacculus. The utriculus gives origin to the three semicircular canals which are arched tubes opening into the utriculus at both ends. The membranous Labyrinth contains a fluid called the Endolymph. The Labyrinth is placed inside the Auditory capsule which contains a fluid called Perilymph. The semicircular canals end in bulb-like swelling at one end which are known as Ampulla. The Ampulla has a projection inside which has long sensory hairs and are connected with the fibres of the Auditory Nerve.

Olfactory Organs :

The olfactory apparatus of the toad consists of the Nasal sacs which open into the exterior by two apertures called the Nostrils, and internally by the posterior Nares inside the mouth.. The olfactory nerve runs into the sac of either side.

Organ of Taste :

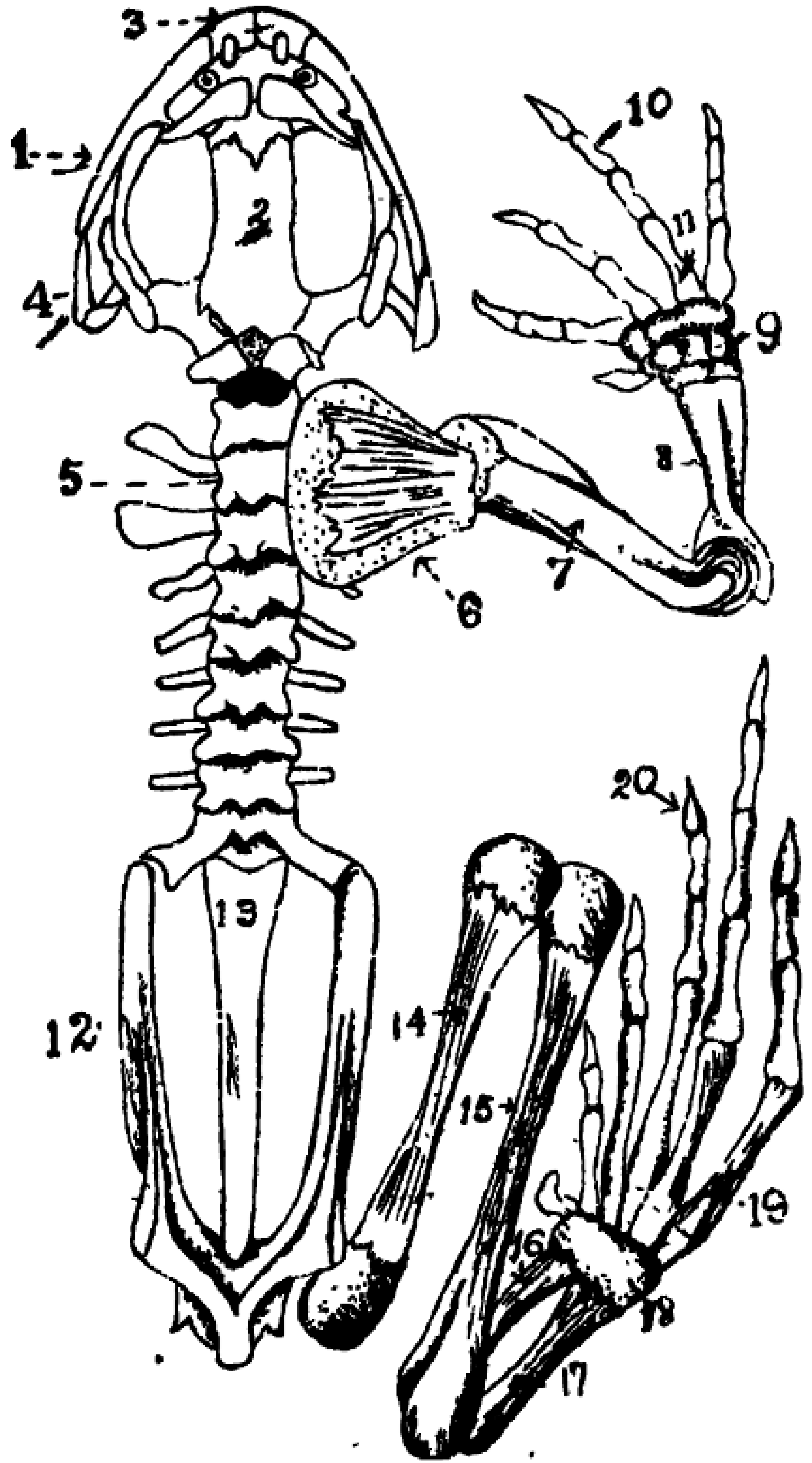
The tongue is the organ of taste. The outer part (external surface) of the tongue is studded with special cells called Taste-buds which give rise to particular sensation. The internal lining of the mouth has to some extent been provided with similar sense organs of taste. It is supplied by the Glossopharyngeal nerve.

Skeletal System or Skeleton :

The back of the skull has a large aperture called the Foramen Magnum which is bounded on either side by the exoccipital bones. Below the foramen magnum are a pair of projection called the occipital condyles which articulate with the first vertebra. On the outer side of foramen magnum is a small aperture for the exit of the 9th and 10th cranial nerves. There is the Pro-otic bone at the side of the exoccipital which fuses with it in the adult stage. The roof of the cranium is formed by the pair of Fronto-parietals which are formed by the fusion of two frontals and two parietals. The two nasals occur in front of the frontoparietals. Between the nasals and the fronto-parietals occur the Sphenethmoid. On the outer side of the pro-otic lies the hammer-shaped or T—shaped squamosal. The slender columella auris projects from the fenestra ovalis beyond the exoccipital. On the ventral aspect in front of the two exoccipitals is the Parasphenoid. The two small Vomers lie in front of the parasphenoid. The Pterygoid lies as a three-rayed bone on the outer side of the parasphenoid. The two palatines are placed anteriorly to the parasphenoid and extend to the pterygoid.

The upper jaw is formed by the premaxilla, maxilla and Jugal. The quadrate is attached to the Jugal and articulates with the lower jaw.

The lower jaw consists of two halves called Rami with a cartilaginous core called the Meckel's Cartilage. On the outer face of it is the Dentary and the Angulo-



1Maxilla, 2—Fronto-parietal, 3—Pre-maxilla, 4—Quadrato-jugal, 5—Vertebra (2), 6—Scapula, 7—Humerus, 8—Radio-ulna, 9—Carpals, 10—Phalange, 11—Metacarpal, 12—Ilium, 13—Urostyle, 14—Femur, 15—Tibio-fibula, 16—Astragalus, 17—Calcaneum, 18—Tarsal, 19—Metatarsal, 20—Phalanx of digit.

Splenial on the inner face but in the adults they are fused.

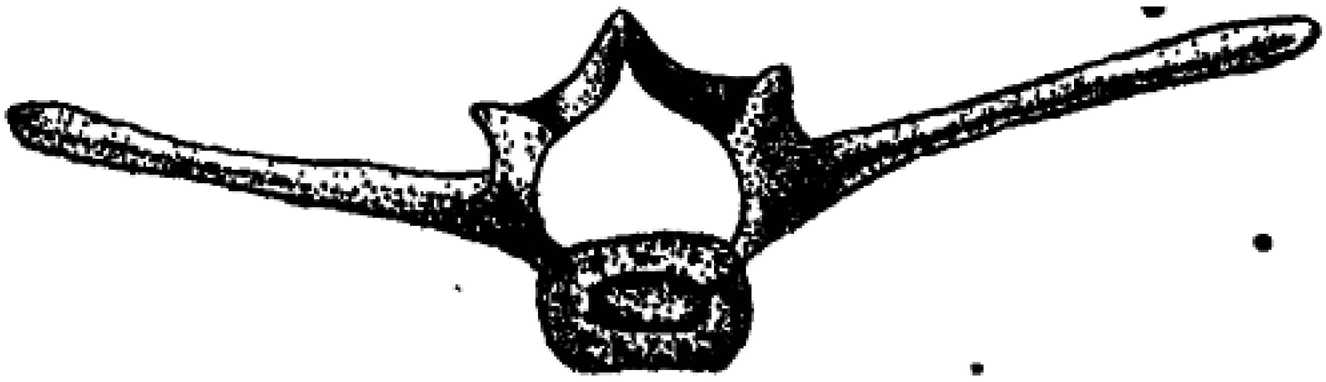
Hyoid :

The hyoid apparatus of toad consists of a shield-shaped cartilage called the Body of the Hyoid. The anterior side is produced into slender rods called the Anterior Cornua and its posterior angles into partly ossified rods called the Posterior Cornua embracing the glottis.

The Vertebral Column :

The Vertebral Column is formed of nine movably united pieces called the Vertebræ and an unsegmented bony rod called the urostyle which represents a number of fused vertebræ of the tail region. Each vertebra looks like a ring and has a solid structure at the base called the Centrum and there is a cavity or hole through which the spinal cord passes down to the tail. The two walls on the two sides are known as Neural arches and a spine-like projection seen at the back is called the Neural spine. The cavity of the arches is known as the

Vertebra



Neural canal. From the two sides of the vertebra projections are found which are called the Transverse Processes. The third vertebra has a large process which is pointed downwards.

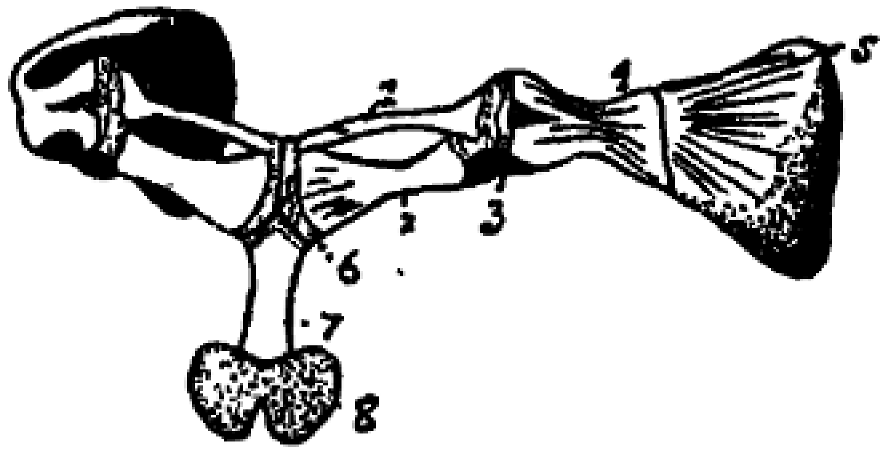
The solid centrum is concave in front and is convex behind. This type of vertebra is called **Procoelous.** The vertebra are joined or articulated with one another by facets or Zygapophyses. On the anterior surface of each vertebra the facets are smooth and flat and are known as Prezygapophysis. On the posterior part the two facets slightly point downwards and are known as Postzygapophyses. The first vertebra has no transverse process. It articulates with the condyles of the skull. The Eighth Vertebra is peculiar in having the centrum concave on both the surfaces and is known as **Amphicoelous.**

The ninth vertebra has two large transverse processes. The urostyle is a bony rod at the tail end of the vertebral column.

The Pectoral or Shoulder Girdle :

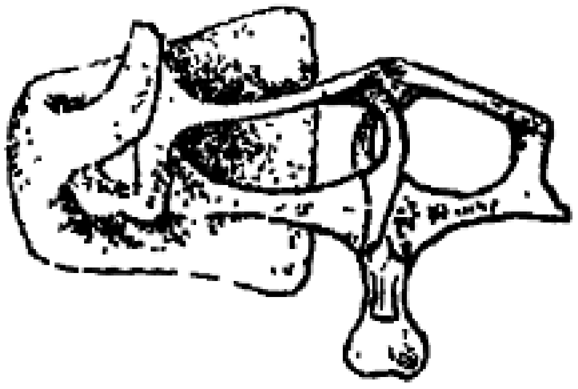
The ninth vertebra has two large transverse processes. scapula at the back. The scapula has another piece called Suprascapula. In the front the girdle has a bone called the Clavicle below which is the Coracoid. The coracoids at their meeting place in front are known as Epicoracoids. In the Toad the Epicoracoids are twisted. There is a breast bone called the sternum which has a cartilage called xiphisternum. In the Toad there is no omosternum. There is a cavity at the junction of the scapula and the coracoid. This is known as the Glenoid cavity and here the bone (Humerus) of the fore limb is attached. The humerus has a ball-like end and the socket is provided by the glenoid cavity. This sort of joint is known as Ball and socket joint which allows the hand considerable freedom of movement.

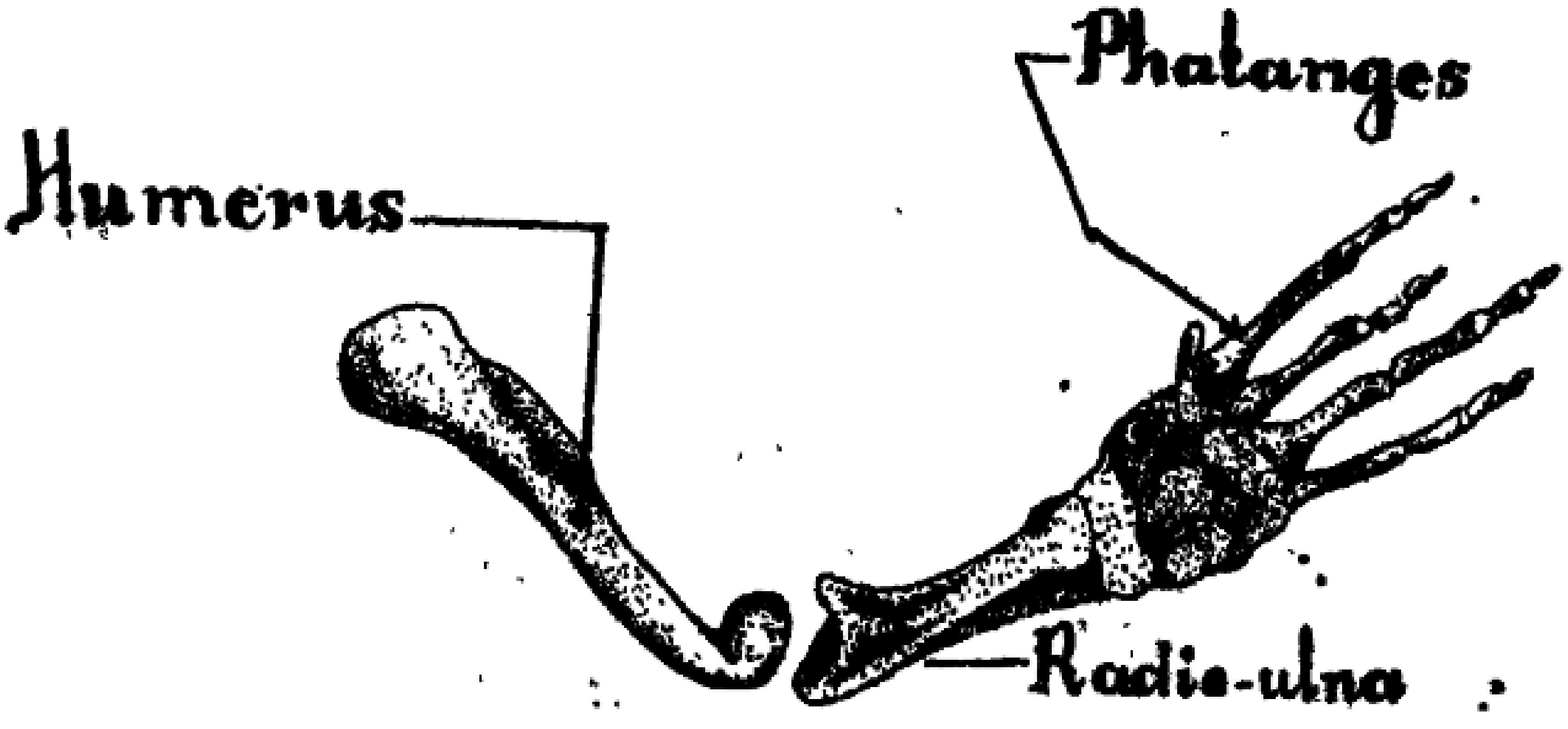
Pectoral girdle of Toad.



1—Clavicle, 2—Coracoid. 3—Glenoid cavity, 4—Scapula, 5—Suprascapula, 6—Epicoracoid. 7—Sternum, 8—Xiphi-sternum.

Pectoral girdle.

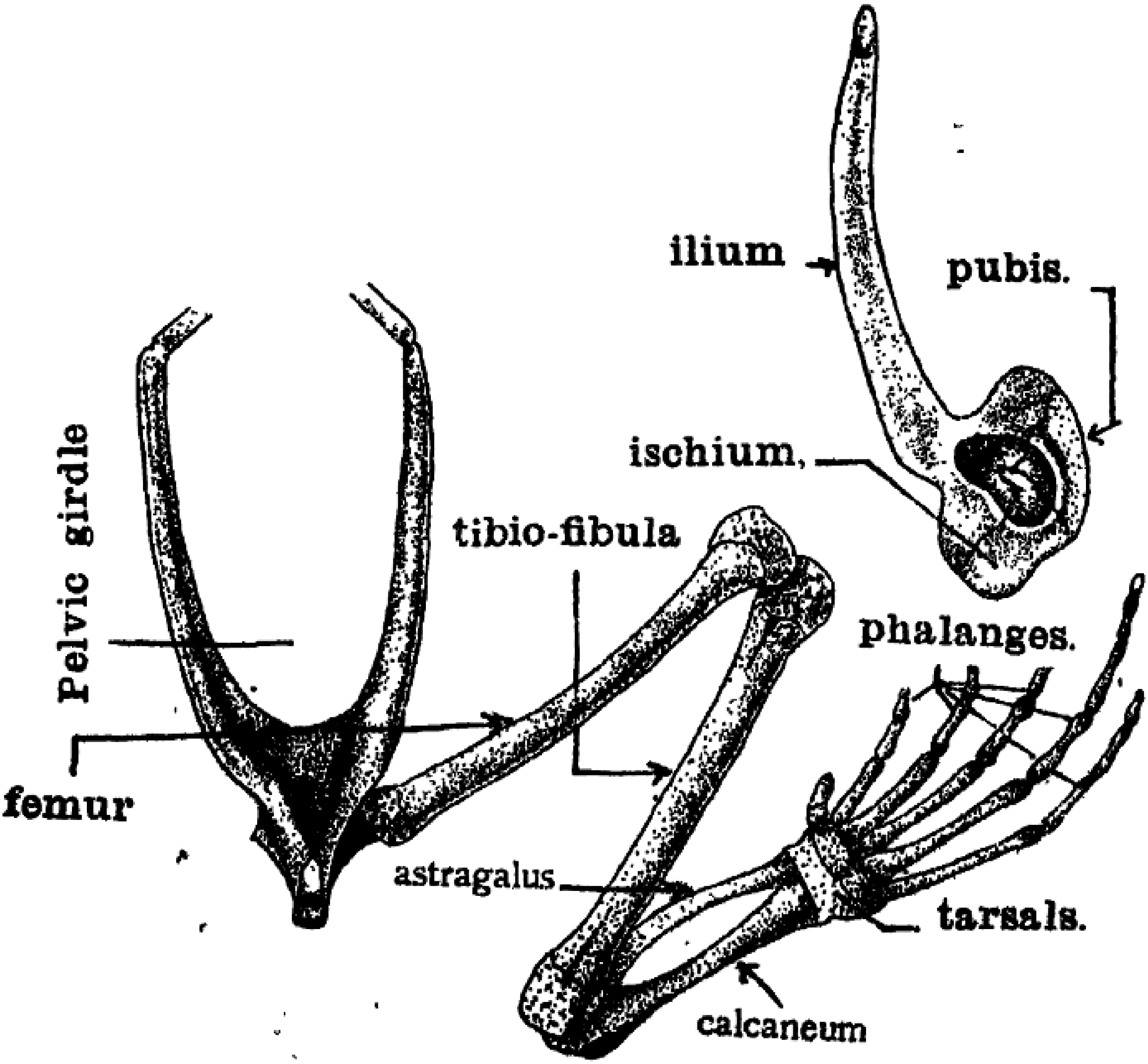




Forelimb of toad

Fore Limb :

The first bone of the forelimb is a long bone called the **Humerus** which has one end in the glenoid cavity and the other end is connected with the **Radio-ulna,** the two bones **Radius** and **Ulna** being fused together. The Humerus has a large head and a prominent ridge. Next come the six pieces of carpal bones arranged in two rows. There are four long slender **Metacarpal** bones with which the four digits of the hand are attached.



Each digit has either two or three phalanges. The phalanges from the radial side are numbered as 2, 2, 3 & 3.

The Pelvic Girdle :

The pelvic girdle has on each side a long bone called the **Ilium** and **Pubis** in front and the **Ischium** below and dorsally. The Pubis is united with its fellow of the other side and is cartilaginous at the junction.

The three bones by their union form a cavity called the **Acetabulum** which is the socket for the Hind limb.

Hind Limb :

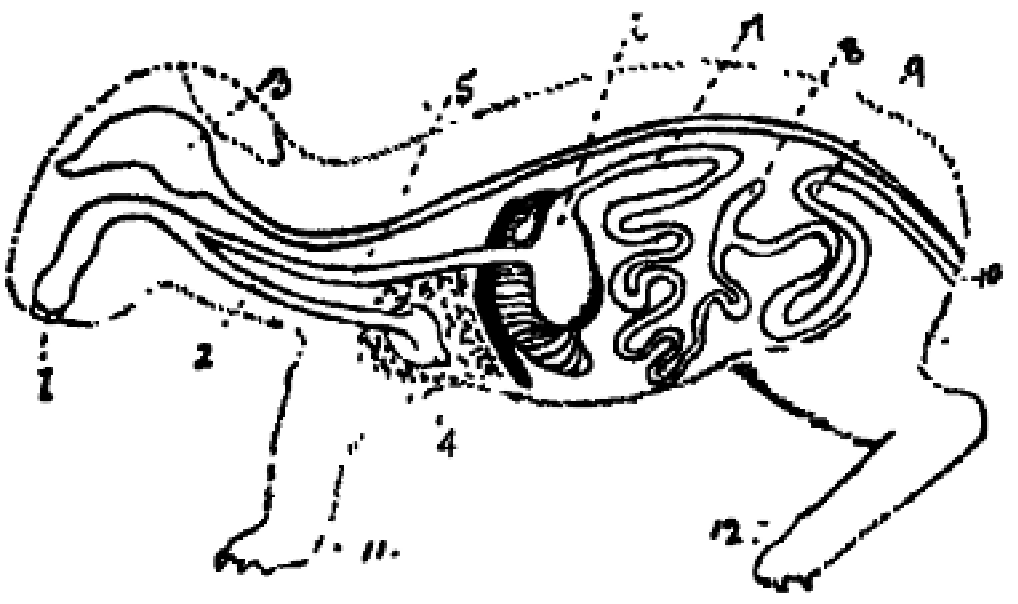
The hind limb consists of a long bone called the **Femur** whose round end called the Head articulates with the acetabulum. The other end has two ridges with a furrow and meets the two other fused bones called **Tibiofibula** and a small bone called the Patella at the knee. The Tibio-fibula articulates with the Tarsus, two of which form the ankle joint and are known as **Calcaneum** (Fibulare) on the outer side and **Astragalus** (Tibiale) on the inner side. The other two bones of the Tarsus are small. The Tarsal bones are followed by the five Metatarsal bones. Each metatarsal bone has a digit consisting of a number of phalanges. The phalanges are numbered 2, 2, 3, 4 and 3 counted from the inner side. On the inner side of the first or big toe called Hallux there is an extra toe or Calcar.

Guineapig :

This animal is a type of the class **Mammalia.** The The word "mammalia" is derived from the Latin root.

"mammæ" meaning breast. All animals belonging to this group namely man, monkey, elephant, tiger, cat, dog and guineapig have to nurse their young ones with the breast milk. It is one of the warm-blooded animals *i.e.*, its temperature is constant and does not depend upon the variations of the medium as atmosphere or water in any way. Therefore the Guineapig is called **homoiothermal** animal. The animal has an external covering of **hairs** which is sometimes coloured. The ventricle of the Heart is completely divided by a partition into two distinct chambers. The Guineapig like all other mammals perspires and gives out some waste products through the pores of its skin.

Section of Guineapig.

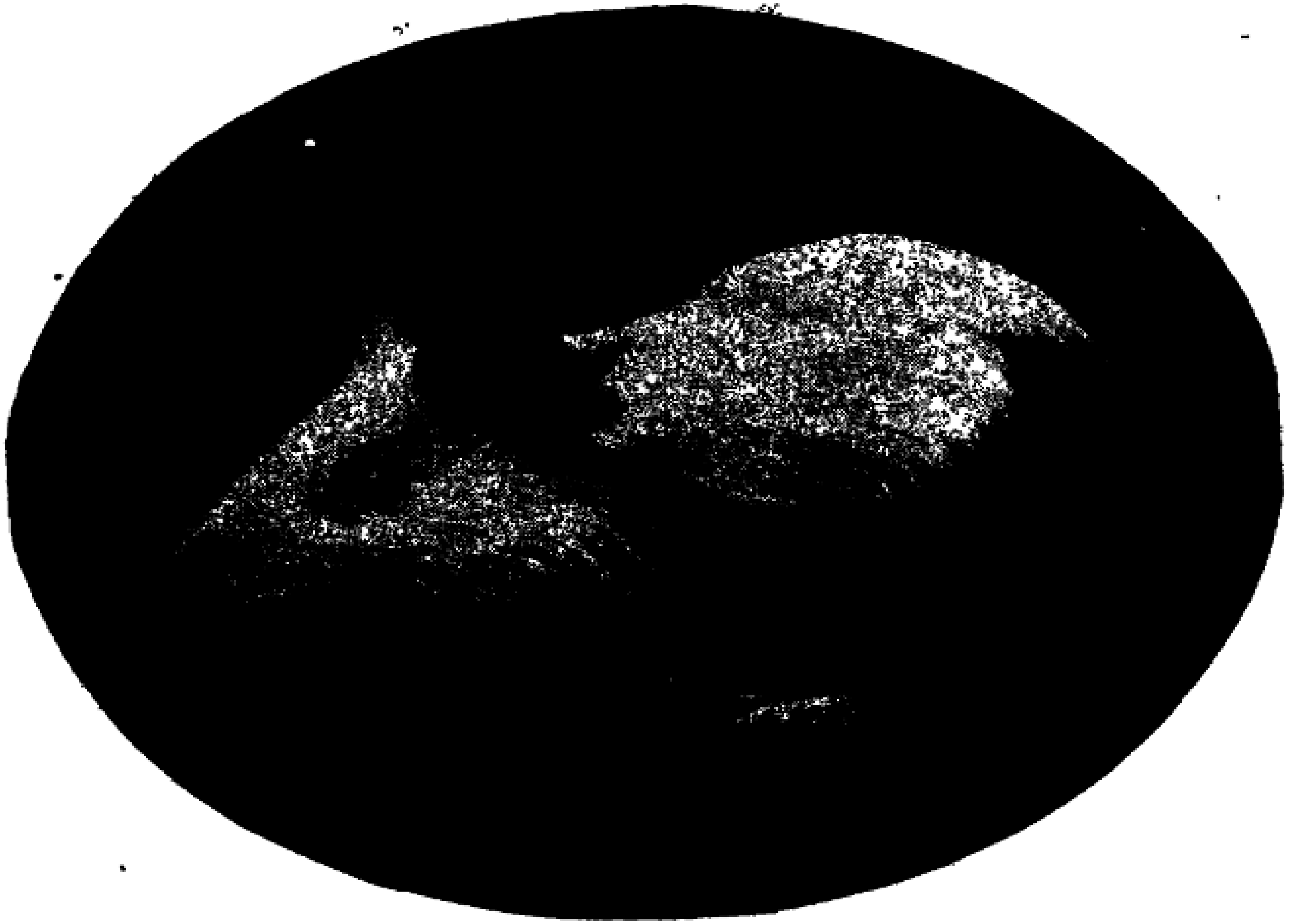


1—Mouth, 2—Trachea, 3—Brain, 4—Lung, 5—Œsophagus, 6—Stomach, 7—Duodenum, 8—Caecum, 9—Rectum, 10—Anus, 11—Forelimb, 12—Hindlimb.

Body—External Features :

The body is divisible into a **head, neck and trunk.** It has no tail. The trunk is divided internally by a partition called the diaphragm into thorax annd abdomen.

MAMMALIA.



The Guineapig.

The thorax is bounded by the ribs and contains the vital organs *viz.*, the Heart and the Lungs. There are two nostrils at the end of the snout. There are two eyes, each eye has two lids, upper and lower and a membrane called the Nictitating membrane. The mouth is placed below the nostrils and has upper and lower lips. The abdomen on the ventral side has teats or mammæ in the female. The anus opens posteriorly by an aperture and the genital organs open by a common opening with the urinary system in the male and by separate apertures in the female.

The forelimb has four digits which are all provided with claws. The hindlimb has three digits which are also clawed.

The skin consists of Epidermis on the outer side, dermis is below or beneath it followed by layers of muscles held together by connective tissue called fascia.

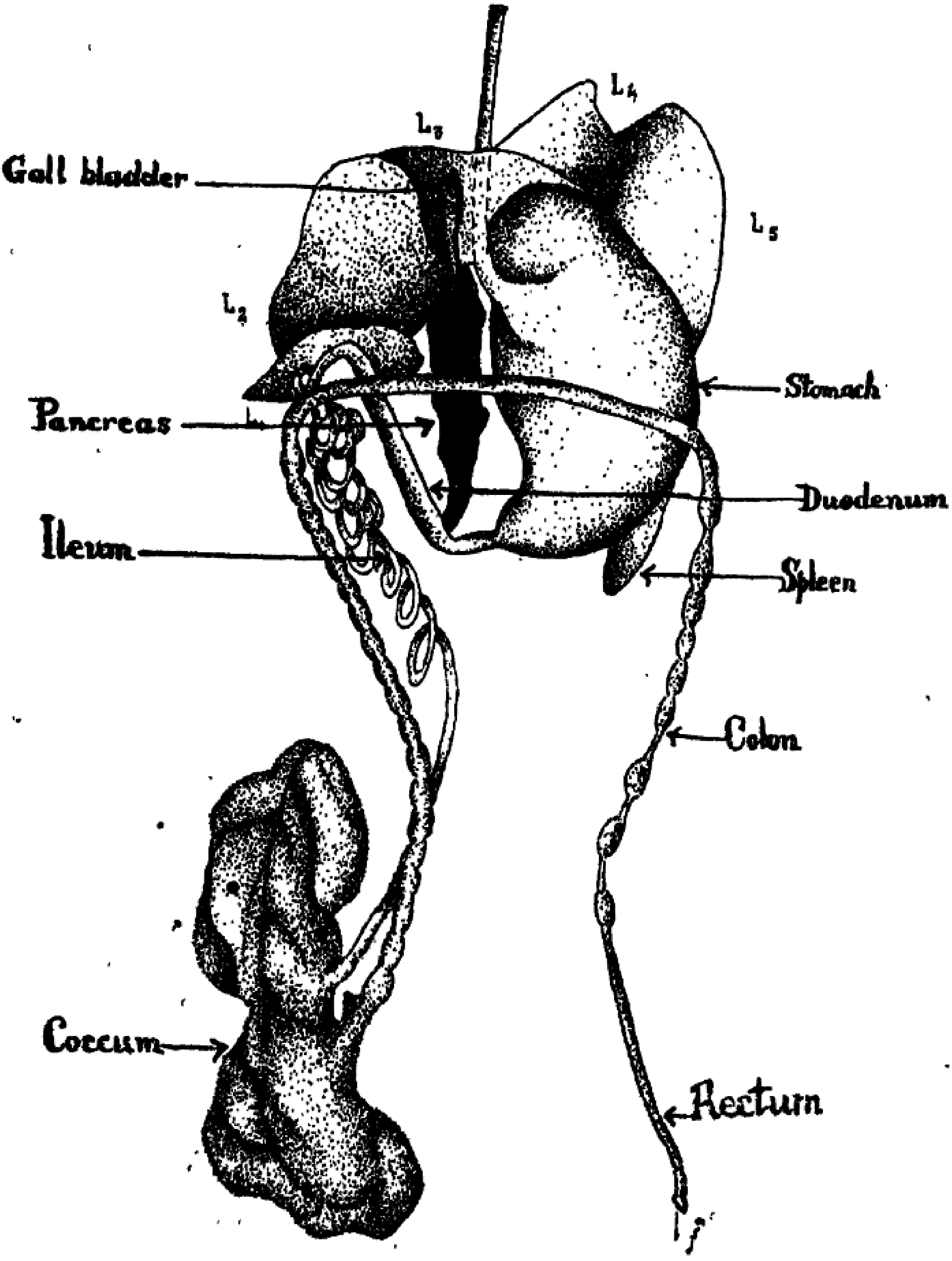
Each ear has three parts *viz.*, the external ear provided with a pinna, the middle ear and the internal ear.

Body-Cavity :

The body-cavity is a cœlome and is divided into thorax and abdomen. The thorax is lined by a membrane called Pleura and the abdomen is lined by a similar membrane called Peritoneum.

Alimentary System :

The mouth leads into a cavity called the Buccal cavity. This cavity has a roof called the Palate which is divided into two portions called Hard palate in front


L4
L3
Gall bladder
L5
L2
Stomach
Pancreas
Duodenum
Ileum
Spleen
Colon
Coecum
Rectum

and soft palate behind. The hard palate is strengthened by palatine bones while the soft palate is entirely fleshy and therefore soft. The internal nares (opening of the nose) of the Guineapig open into the back of the mouth called the Pharynx. The tongue is an elongated muscular organ which covers the floor of the mouth with the tip free in front. The teeth are not all alike and are planted in sockets on the jaw bones. The front teeth are large, chisel shaped and slightly curved. They are used for cutting away delicate vegetables which the animal eats as food and are known as Incisors. Then there is a free space on each side on both the upper and lower jaws which is known as Diastema. The Canine teeth are absent in the Guineapig as it is not a flesh-eating animal. The gap above mentioned would have been occupied by the Canines had they been present. Then there is one premolar and three molars on each side of both upper and lower jaws. The dental formula therefore is :—

$$I\tfrac{1}{1}\ C\tfrac{0}{0}\ Pm\tfrac{3}{3}\ M\tfrac{1}{1}$$

giving ten teeth on either side or 20 in all.

Inside the buccal cavity four salivary glands open on each side by ducts. The Infraorbital gland is placed just below the eye. The Parotid gland lies in the cheek. The submaxillary lies near the angle of the mandible and the sublingual is situated on the inner side of the ramus of the lower jaw. The back portion of the buccal cavity is called the Pharynx. It has two divisions, one above, which is called the Nasal portion where the posterior nares opens and also contains the openings of the two eustachian tubes. The other division is called the Buccal portion which contains two apertures of which one is known as the Glottis and is guarded by a flap of cartilage called the epiglottis which leads into the respiratory organs. The other aperture leads into the alimentary canal, and is behind the glottis.

The first part of the alimentary canal is a narrow tube called the **oesophagus.** The œsophagus goes down through the thorax and by a perforation through the Diaphragm enters the Abdominal cavity, where it opens into a dilated sac called the **stomach.** The stomach has two ends, the one at the junction of the œsophagus is known as the **Cardiac end** while the other from which the intestine beings is known as the **Pyloric end.** The stomach has many glands on its inner wall which help digestion by their secretion.

.The intestine is a much coiled tube and is divided into two portions *viz.*, the **small intestine** and the **large intestine.** The small intestine begins from the stomach and is again divided into two portions *viz.*, the **Duodenum** and the **Ileum.** The Duodenum is a short U-shaped tube followed by the much coiled Ileum. The Ileum is followed by the **Large Intestine.** The Large Intestine again has three divisions. The first portion of the Large Intestine is called the **Caecum** which is a thick dilated tube and ends in a process in man called the Vermiform Appendix but in the Guineapig there is no trace of Vermiform appendix found. The **colon** begins from one side of the Cæcum and is much coiled and ends in a tube called the **Rectum** which opens into the exterior by an aperture called the **Anus.**

Liver :

This is the largest gland in the body of the Guineapig and is **five-lobed.** It lies below the diaphragm resting on the stomach. It has five deeply coloured lobes. The gall gladder lies as a pyriform sac on the posterior border of the Liver. The Liver sends out a secretion which is called the Bile. It helps digestion. It comes out through a duct called Hepatic duct which opens into the Duodenum after uniting with another similar duct from the Gall-bladder which is called the Cystic duct. The united duct is known as the Common Bile duct as both of them carries the bile to the intestine.

Pancreas :

The pancreas is a whitish gland lying in the concavity of the duodenum and extending up to the wall of the abdomen. It has a duct which also opens into the duodenum and the secretion of the pancreas helps digestion.

The coils of the intestine and the stomach are suspended from the vertebral Column and kept in position by folds of peritoneum which are called the Mesentery.

Circulatory Organs :

The Heart, the principal organ of circulation, the central pumping station of blood in the body, is situated in the Thorax lying between the pleural sacs enclosing the Lungs. The heart is covered by a membranous sac called the Pericardium which contains a fluid called the pericardial fluid. The heart of the Guineapig has four chambers called the left auricle and left ventricle on the left side and the right auricle and right ventricle on the right side. The right and left sides of the heart having their cavities completely and fully separated from one another by partitions called Interauricular and Interventricular Septa.

Right Auricle or Atrium :

The right auricle receives the three large veins called the right and left precaval veins and the single postcaval vein. The right auricle communicates with the right ventricle by a wide opening called the Right Auriculoventricular opening which is guarded by a valve called the Tricuspid composed of three membranous lobes or cusps so arranged that they allow the blood to pass from the right auricle to the right ventricle only and not otherwise. And when the right ventricle contracts the flaps meet and close the aperture so that the blood can pass in one direction only. The Right ventricle is much thicker than the right auricle. The walls inside the cavity are raised up into muscular ridges called the Columnæ Carnæ. The Right Ventricle from its anterior angle gives out the Pulmonary artery the entrance to which is guarded by the three semilunar valves.

Left Auricle or Atrium :

The left auricle like the right one has an auricular appendix. It receives pure blood from the two pulmonary veins which open together from the Lungs. The left auricle communicates with the Left ventricle by the left Auriculoventricular opening which is guarded by the Biscuspid or Mitral Valves consisting of two flaps or cusps.

The Left Ventricle is more thick-walled and stronger than the right one. It has columnae carnæ also. At the base of the left ventricle is the opening of the Aorta, the principal arery for the distribution of blood to the system. Its opening is guarded by three semilunar valves. There is no Sinus Venosus.

The Arterial System :

As the name signifies this system consists of arteries which are vessels meant to carry pure or oxygenated blood from the Heart to the different parts of the body. These vessels have thicker and elastic walls than the veins which carry impure or deoxygenated blood from the different parts of the body to the Heart. The main trunk of the arterial system of the Guineapig arises from the base of the left Ventricle. It then forms an arch and is known as the Arch of Aorta. The Aorta gives rise to a number of smaller arteries as branches. In the case of all mammals the Aorta bends only to the left side which is a peculiarity to be noted.

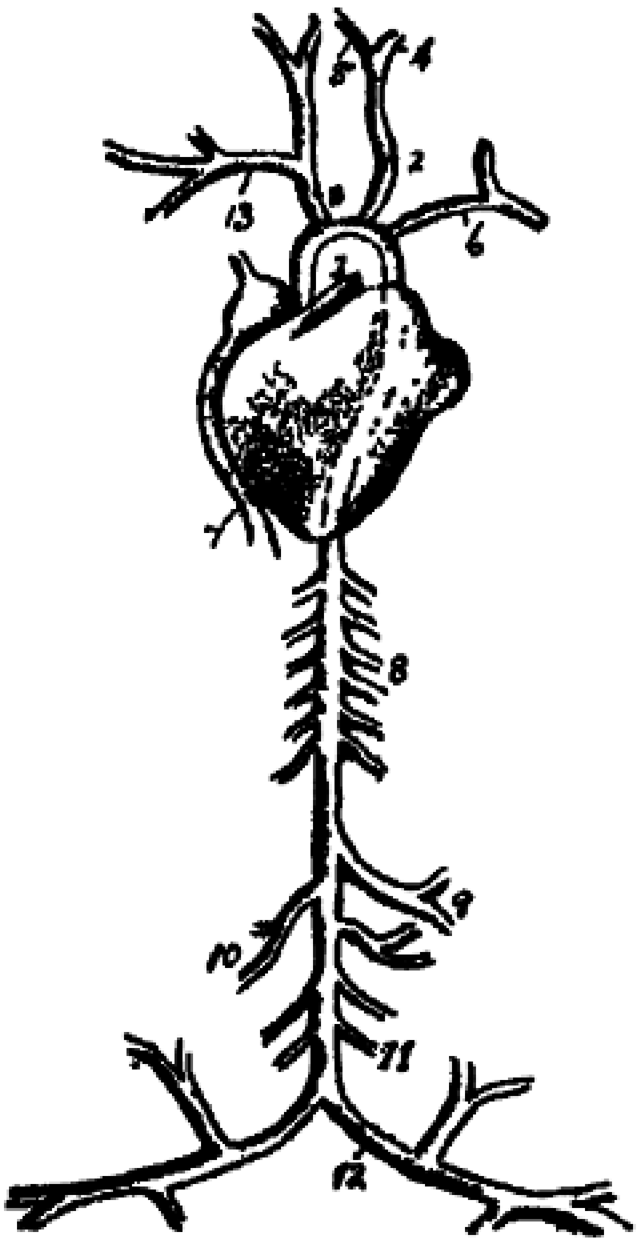
Branches :

The first important branch is the Innominate artery which arising from the arch divides into Right common carotid and the Right subclavian artery and a left common carotid; The **Right common carotid** divides into right external carotid supplying the right half of the head and face and **Right Internal Carotid** supplying the right half of the Brain. The **Right Subclavian** passes into the right arm as Right Brachial. Before passing to the arm it gives off two branches, one to the ventral thoracic wall which is known as the Internal Mammary artery and the other enters the vertebral column as the Vertebral Artery.

The Left Common Carotid arises from the innominate and supplies the left part of the head and face with two branches from it named the **Left Internal Carotid** and the **Left External Carotid.** The Left Subclavian artery arises independently from the Arch of Aorta and passes to the arm as Left Brachial and gives off similar two branches *viz.,* Left Internal Mammary and Vertebral to supply similar areas like the right side.

Arterial System.

1—Arch of Aorta,
2—Left common carotid,
3—Innominate,
4—Int. carotid,
5—External carotid,
6—Sub-clavian,
7—Postcaval vein,
8—Intercostal,
9—Coeliac,
10—Renal,
11—Posterior mesenteric,
12—Iliac.



Left carotid should arise from innominate.

The **Arch of Aorta** then passes down the back of the Heart and is placed ventral to the spinal column and is known as the **Dorsal Aorta.** The Dorsal Aorta may be divided into **Thoracic Aorta** and **Abdominal Aorta** according as it passes through the thorax and abdomen respectively. The Thoracic Aorta gives off a number of branches called the **Intercostal arteries** which supply the wall of the thorax.

The **Abdominal Aorta** gives off the following important branches *viz.*:—

(1) **Coeliac** which supplies the Liver, stomach and spleen.

(2) **Anterior Mesenteric** which supplies the intestines and Pancreas.

(3) **Two Renal arteries** to the two kidneys.

(4) **Two ovarian** in the female or **two Spermatic arteries** in the male. The ovarian arteries supply the ovaries and the spermatic supplies the testis.

(5) **Posterior Mesenteric** artery supplies the Rectum.

(6) The Dorsal aorta ultimately divides into two **Iliac** arteries. Each Iliac artery divides into External Iliac and Internal Iliac arteries. The External Iliac supplies the hind-limb as Femoral artery. The Internal Iliac artery supplies branches to the Bladder and lower abdominal organs.

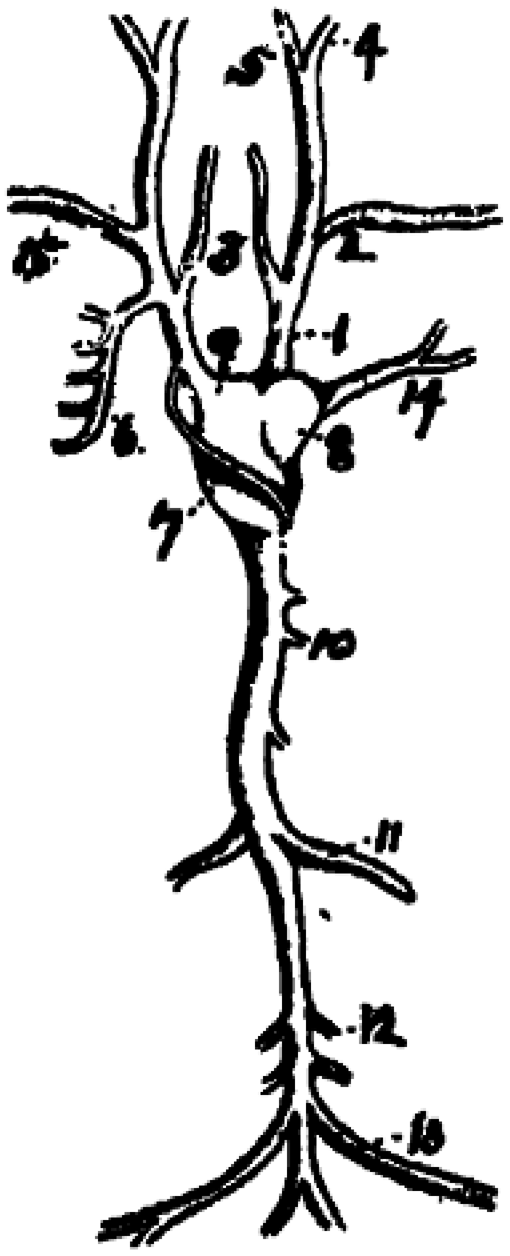
The **Pulmonary Artery** arises from the Right ventricle and divides into Right and Left Pulmonary arteries and each of them goes to the Lung of that side.

The Venous System :

The veins are vessels which bring impure blood from the different parts of the body back to the Heart. The veins are thin-walled and contain no elastic fibres and run superficially on the body. There are three principal veins (the body of the Guineapig) two of them bring blood from the region of the head and are known as the Anterior Venæ Cavæ. Each anterior Vena Cava or Precaval vein is formed by a number of veins. They are :—

Venous System.

1—Precaval,
2—Sub-clavian,
3—Internal jugular,
4—Posterior facial,
5—Anterior facial,
6—Intercostal,
7—Azygos,
8—Auricle,
9—Auricle,
10—Hepatic,
11—Left Renal,
12—Genital,
13—Femoral or Ext. iliac. vein,
14—Pulmonary vein.



(1) **External Jugular** from the surface of the head.

(2) **Internal Jugular** from Brain.

(3) **Subclavian** from shoulder and forelimb.

The Right Anterior Vena Cava also receives a vein called Azygos from the wall of the chest.

(4) **Anterior Intercostal** from the anterior thoracic wall.

There is a single Posterior Vena Cava or Post Caval vein which lies by the side of the Dorsal Aorta. It is formed by the following veins :—

(1) The **two Internal Iliacs** from the back of the two thighs.
(2) The **two External Iliacs** from the inside of the two thighs.
(3) The **two Ilio-lumbars** from the abdominal walls.
(4) The **two genital veins** from the reproductive organs.
(5) The **two Renal veins** from the two kidneys.
(6) The **two Hepatic veins** from the liver.

The **Renal portal system** is not found but there is a Hepatic portal system. Blood is brought to the Liver by a number of veins from the parts of the Alimentary Canal and they join to form the Hepatic Portal vein.

The **Pulmonary veins** bring pure blood from the two lungs to the Heart but before opening into the left auricle, the two veins combine. Although the name vein is given to the Pulmonary veins but actually they carry pure oxygenated blood from the Lungs to the Heart.. This is an exception. A similar exception is also found in the case of the Pulmonary artery which carries venous blood from the Heart to be purified in the Lungs.

Blood :

The blood of Guineapig like all mammals except that of Camels consists of a fluid portion called Plasma in which float white and red corpuscles. The white blood corpuscles are all nucleated and amœboid in nature. The red blood cells are non-nucleated and biconcave disks. They are not amœboid in nature.

Circulation :

The Circulation in the Guineapig is divisible into greater circulation and lesser circulation. The greater circulation consists of blood running through the body and the lesser circulation through the lungs. The greater circulation in the venous blood being brought from the three principal veins to the Right Auricle and then to the Right ventricle. The pure blood from the Left Auricle passes to the left ventricle and is then distributed by the Aorta to all parts of the body. The Arteries are connected by intermediate structures which are very fine and net-like and are known as Capillaries.

Circulation.

1—Ventricle.
2—Artery.
3—Art,
4—Capillary,
5—Cap of
Lungs.

The circulation in the Lungs consists in the carriage of the blood from the Right ventricle by the Pulmonary artery to the Lungs. And from the Lungs the blood returns to the Left Auricle by the Pulmonary veins.

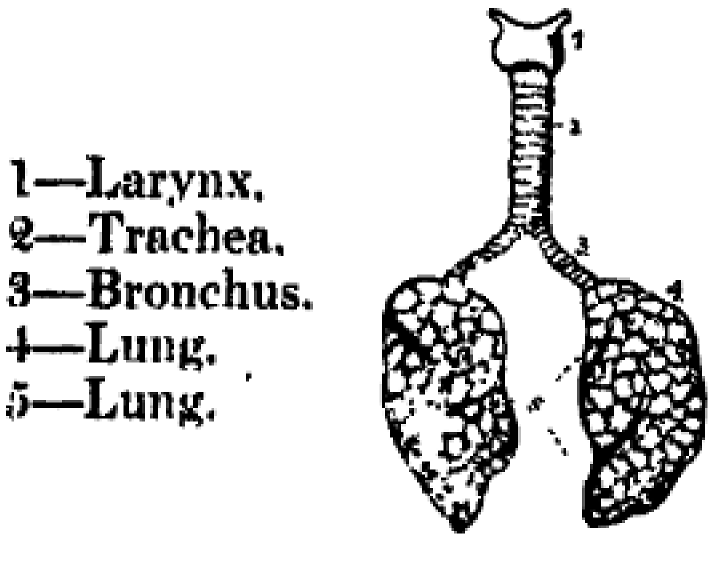
The Hepatic Portal System :

The portal vein brings blood from the intestine which is rich in nutritive material absorbed from the alimentary tube and also impure venous blood from other hinder region of the body. This mixed blood enters the Liver and after receiving blood from the Hepatic veins is then poured into the greater circulation.

The Respiratory System :

The Respiratory apparatus of the Guineapig consists of three parts *e.g.*, Larynx, Trachea and the Lungs. At the back of the mouth there is an aperture called Glottis which is guarded by a flap of cartilage called the Epiglottis.

Lungs of Guineapig.



The Epiglottis prevents all foreign matter from entering the glottis and closes the aperture when food is passing to the alimentary tube. The glottis leads into a chamber called the Larynx. The Larynx is made of cartilage of which there is a large one in front called Thyroid, a ring like another called the cricoid and other two in the middle called Arytenoids. Then there are two membranous cords in the Larynx called the Vocal Cords. The Larynx is also called organ of voice. The vocal cords produce sound by the vibration of the air which comes from the Lungs.

The Larynx is continued into the Thorax as a tube called the Trachea. The Trachea is made of cartilage rings which are incomplete dorsally. The Trachea divides into two smaller tubes called Bronchi which are also made of cartilage. They eventually enter into the Lungs. Inside the lung each Bronchus ramifies into finer branches and are known as Bronchioles.

Lungs :

Two spongy sacs are found inside the Thorax called the Lungs. Each lung lies inside a sac called the Pleura. The lungs are very vascular and there are rich capillaries joining the Pulmonary arteries with the Pulmonary veins. Here exchange of gases takes place. Each lung is divided into lobes (Three on the left side and four on the right side).

Respiration consists of two processes *viz.,* Inspiration by which oxygen is taken in and Expiration by which carbon dioxide is driven out. During inspiration muscles of the chest as also the Diaphragm and some muscles of the abdomen and neck contract and as a result the lungs become distended with the distention of the thoracic cavity as a result of which a negative pressure is exerted so that air is sucked in. The air enters through the nostrils, passes down the Larynx and Trachea and enters the Lungs. During expiration the muscles of the chest and Diaphragm relax and the Lungs recoil from the elasticity of their walls. They contract and drive out the gases from the lungs. The two processes are always going on alternately and form what is known as Respiration.

Endocrine Organs :

There are some organs in the Guineapig which have no definite passages but their secretion is necessary for the due discharge of its bodily functions. They are the following :—

(1) Thyroid lying in front of the trachea near the cricoid cartilage.

(2) Thymus is generally present in the young animal near the base of the Aorta.

(3) Spleen occurs on the dorsal side of the stomach on the left side.

(4) Suprarenal gland two in number, each lying on the top of the kidney.

(5) Pituitary Body is found on the ventral aspect of the Brain.

These glands send their secretion to the blood stream directly and help the various functions of the body as growth, maturation of the generative organs etc.

The Excretory System :

The excretory system of Guineapig consists of two dark red kidneys, one on each side of vertebral column and lying within the abdominal cavity. Each kidney is a bean-shaped body and is covered over by the peritoneum. Each kidney has a passage called the ureter which begins at the hilus and the two ureters from the two kidneys open at the lower part of a sac-like organ called the urinary Bladder. The urine comes from the kidney through the ureter and collects in the Bladder. The Bladder has got a passage called the urethra through which the urine is voided from time to time as the bladder gets filled up.

The kidney is surrounded by a sheath and on section the inner portion is seen divided into (*a*) an outer portion called the Cortex and (*b*) an inner portion called the Medulla.

The cortex consists of tubules. Each tubule has a capsule called the Malpighian capsule at the distal end and is convoluted till it ends in the collecting tubule. The tubules open on the surface of a conical process called the Pyramid which projects into the Pelvis which is the innermost sac of the kidney. The ureter begins from the Pelvis. In the male the urethra is continued into a long organ called the Penis. In the female the urethra opens by a separate aperture.

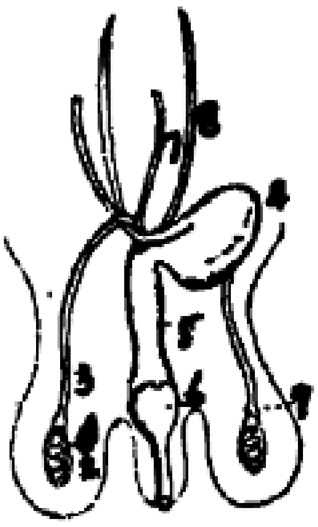
The Reproductive System :

Male --

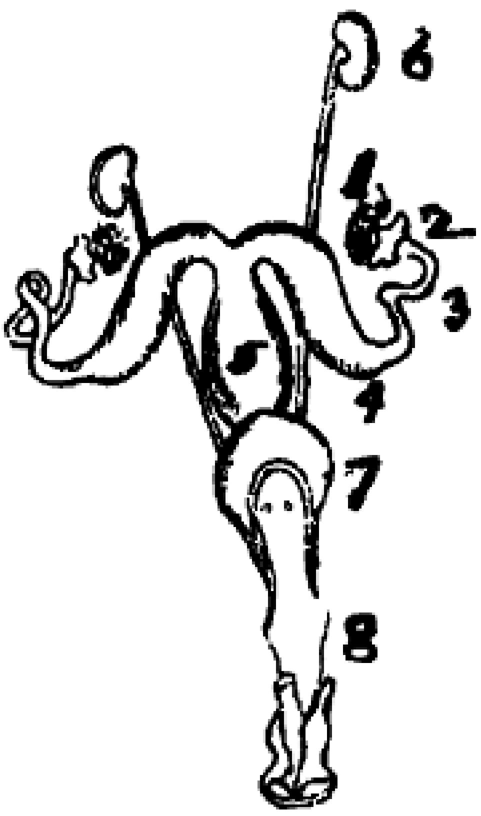
The generative organs of the male animal are the two testes which lie within the abdominal cavity, but come down to the scrotal sac in the breeding season. Each Testis gives off a number of male cells called Sperms. Each sperm has a large head and a long tail which gives it the power of movement. The cavity of the scrotal sac communicates with the abdominal cavity by a passage called the Inguinal Canal. The testis is covered by a closely adhering duct called the epididymis and from this runs the Vas Deferens, the duct of Testis.

The Vas Deferens carries with it nerves and blood vessels as it enters the abdominal cavity and makes a loop round the ureter of the corresponding side between the spermatic sac which is also called the uterus masculinus and the neck of the bladder. It is then continued as the urethra or Urogenital canal. The uterus masculinus in which the sperms are stored, opens at the neck of the Bladder on the dorsal side. The Prostate gland is embedded in the wall of the uterus masculinus and has small ducts which open into the urethra. There is a pair of smaller glands called Cowper's glands which also open into the urogenital canal.

Male organs.



1—Testis.
2—Epididymis,
3—Vas deferns,
4—Bladder.
5—Urethra.
6—Penis.
7—Ureter.
8—Uterus masculinus,
9—Caput epididymis.



1—Ovary,
2—Oviduct.
3—F. tube.
4—Uterus
5—Ves.
6—Kidney.
7—Vag.
8—Opening.

The urethra runs as a median passage through the Penis and is covered by a soft vascular portion called the Corpus spongiosum on the ventral side and Corpora Cavernosa on the dorsal side.

Female —

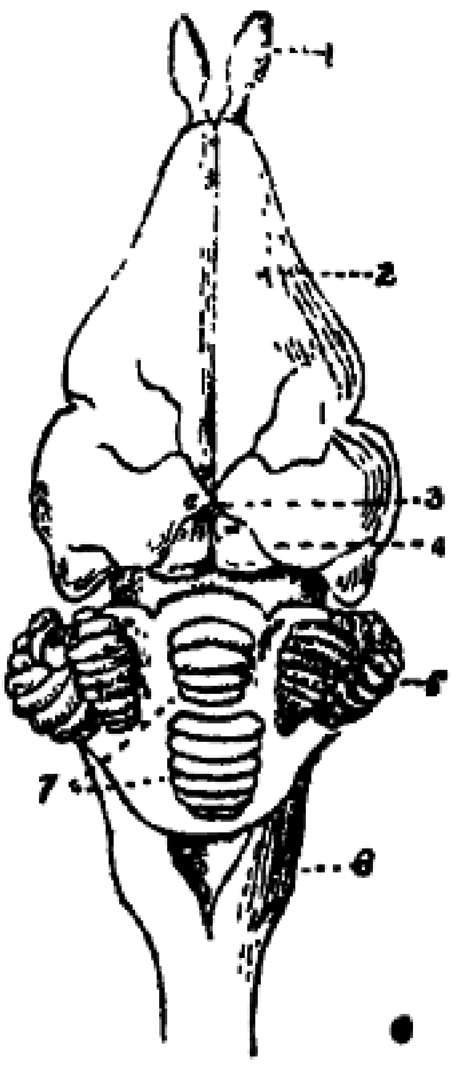
The generative organs of the female are the two ovaries one on each side lying on the dorsal wall of abdomen, and behind the kidneys. The female cells called the ova are formed from the germinal epithelium of the ovary. Some of these become large and become the ova while the others remain small and serve for nutrition of the larger cells. When the animal is adult and the ovary is mature, the ova come out by the bursting of the ovarian wall and are shed into the abdominal cavity. The ova then make their way to the mouth of the oviduct. There are two ducts to the two ovaries called the oviducts. Each oviduct has a funnel-shaped fimbriated mouth at its anterior part near the ovary and a slighly coiled tube called the Fallopian tube. The next portion of the oviduct is called the uterus. The two uteri join and form a common passage called the Vagina. The ultimate part becomes common with the neck of the bladder and forms the Vestibule. It opens to the exterior by the Valva.

The fertilised ovum is lodged in the uterus. It receives nutrition from the mother through a tissue called the Placenta. The uteri become dilated when six or seven young ones are carried by the animal. It takes about 30 days for the full development of the individual young animals. The Guineapig becomes adult in about three months after which it becomes possible for the adult to reproduce young animals.

Nervous System :

Brain —

The Brain of Guineapig consists of two very large cerebral hemispheres or Cerebrum occupying about two-third of the whole brain matter. They cover the Thalamencephalon and the optic lobes. The two hemispheres are joined by a band of nerve fibres called the Corpus Callosum. Each cerebral hemisphere has three portions called the Frontal lobe, the Parietal lobe and the Temporal lobe. There are two very large clubshaped olfactory bulbs at the anterior extremeties of the cerebral hemispheres. The cavities within the cerebral hemispheres are called the Lateral Ventricles. The lateral ventricles are connected with the third ventricle by the Foramen



Brain

1—Olfactory lobe,
2—Cerebral hemisphere,
3—Pineal body,
4—Optic lobes,
5—Flocculus,
7—Vermis,
8—Med. oblongata.

of Monro. The thalamencephalon is overlapped by the cerebral hemispheres. The Pineal body arises from the roof of the thalamencephalon while the floor is produced downwards into a process called the Infundibulum to which the Pituitary body is attached. On the ventral side the optic nerves cross each other and form the optic Chiasma.

In the mid-brain the dorsal part shows that each optic lobe is divided into two portions by a transverse furrow so that two pairs of lobes called the Corpora Quadrigemina are produced.

In the hind-brain the cerebellum appears very large and consists of a central lobe or Vermis and two lateral lobes which are divided by numerous fissures, into a large number of convolutions. Each lateral lobe has a prominence called the flocculus. On section the Cerebellum shows a tree-like pattern.

The Medulla oblongata lies below the Cerebellum and its cavity is known as the Fourth Ventricle.

Cranial Nerves :

There are twelve pairs of cranial nerves in the Guineapig. Two additional pairs are seen namely the spinal Accessory and the Hypoglossal which are absent in the Toad. The nerves are as follows :—

. The Olfactory nerve supplies the nose.

2. The optic nerve crosses its fellow and forms the optic chiasma and then supplies the eye.
3. The Oculomotor nerve supplies the muscles of the eyeball.
4. The Pathetic nerve supplies the superior oblique muscle of the eyeball.
5. The Trigeminal is a comparatively big nerve. It has a ganglion called the Gasserian ganglion and divides into three branches :—
    (a) Ophthalmic—which supplies the eyeball and some part of the head.

(*b*) Maxillary—which supplies part of the face.

(*c*) Mandibular—which supplies the muscles of the jaw.

6. The Abducens supplies the external Rectus muscle of the eye.
7. The Facial nerve supplies the face and supplies a gustatory nerve to the tongue.
8. The Auditory nerve supplies the internal ear.
9. The Glossopharyngeal nerve supplies the pharynx, tongue and neck.
10. The Vagus or Pneumogastric nerve is the most important as it supplies most of the vital organs as Larynx, Trachea, Heart, Lungs and stomach.
11. The Spinal Accessory nerve arises from the side of the Medulla by a number of roots and emerges from the skull along with the 9th and 10th nerves through the posterior lacerated foramen and supplies certain muscles of the neck.
12. The Hypoglossal nerve arises by several roots from the ventral aspect of the Medulla in the middle line and comes out of the skull through the condylar foramen to supply the muscles of the tongue.

Spinal Cord :

The spinal cord passes through the vertebral column and gives out a number of Spinal Nerves. Each nerve arises by two roots, *viz.*, one anterior and the other posterior which join together before the nerve proceeds forwards. There are several plexuses in the spinal nerves *viz.*, cervical and brachial plexuses with the cervical nerves and lumbosacral plexus with the lumbar and sacral nerves. The most important among the spinal nerves is the Phrenic from the fourth cervical nerve which runs backwards and supplies the Diaphragm.

Sympathetic System :

The sympathetic system consists of two cords with two ganglia on each side in the neck, twelve pairs of ganglia in the thorax and twelve pairs in the abdomen. From the hinder thoracic ganglion there starts a splanchnic nerve which runs backwards in the abdomen and ends with its fellow forming Coeliac ganglia round the anterior mesenteric artery. This ganglion having a number of nerves uniting and branching from it constitute the Solar Plexus. A smaller plexus lies around the Posterior Mesenteric artery.

Sense Organs :

The organs of sense in the Guineapig consists of the eyes, ears, tongue, nose and touch.

Eyes :

There are two eyes the structure of which generally resembles that of the Toad except that the Guineapig has the additional Lachrymal or Tear glands. These are situated above the outer corner of each eye as well as the Harderian glands which are similarly situated. The secretion of these glands trickles over the conjunctiva and then passes into the nose by the nasal duct at the inner angle of each eye.

Ears :

The Ear of the Guineapig is its organ of hearing. It has three parts *e.g.*, the External ear, the Middle ear and the Internal ear.

The External ear has the Pinna which is meant for catching the vibrations of sound and is extended by a canal up to the drum or tympanic membrane.

Internal to the membrane and extending up to the bony labyrinth is another cavity called the Middle ear or Tympanic cavity. This cavity communicates with the Pharynx by a tube called the Eustachian tube. Three pieces of small bones are found in the middle ear called the Malleus, Incus and Stapes which are connected to each other and extend from the drum to the Fenestra ovalis of the bony labyrinth. They conduct the vibrations of sound from the external ear to the internal ear.

The Internal Ear consists of the bony Labyrinth with two openings called Fenestra Ovalis and Fenestra Rotunda both of which are covered by membranes. The bony labyrinth contains within it a membranous labyrinth. The bony labyrinth is filled with fluid called Perilymph which lies outside the membranous labyrinth but there is fluid also inside the membranous labyrinth which is called the Endolymph. The membranous labyrinth consists of the utricle with three semicircular canals and a saccule which is connected with the bony Cochlea. The Cochlea has spiral turns like a conch. This cochlea has the Endings of those fibres of the Auditory nerve which subserve the sense of hearing.

Organ of Taste :

The tongue, although a muscular structure, serves as the organ of taste. There are special cells called Taste-buds found on the surface of the tongue and also a few on the palate which are the endings of special nerve and perform the function of taste of the animal.

The Nose :

The epithelium of the nostrils is endowed with special nerve endings of the Olfactory nerve which serve as the organ of smell.

The Sense of Touch :

This sense is developed on the skin due to the presence of Touch Corpuscles which are specialised structures containing ramified special Nerve Endings The sense of touch is specially developed on the pad of the foot and on the skin of the lips in the Guineapig

Skeleton :

The skeleton of the Guineapig consists of bones distributed through out the body and are meant for the support of the soft structures.

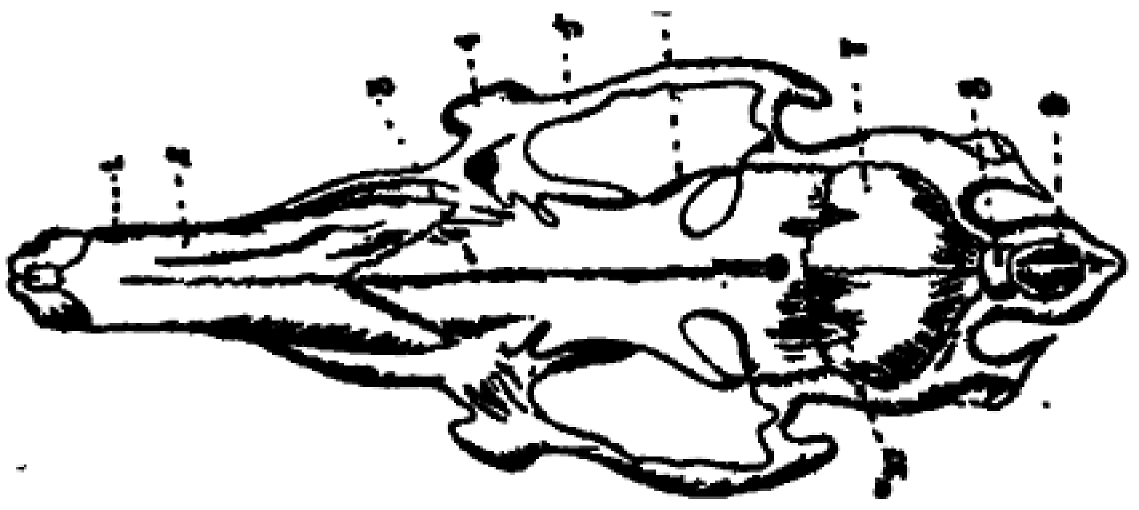
There is a bony case for the Brain which is called the skull or cranium formed of a number of bones. There is an aperture in the skull situated below and posteriorly. At the dorsal part of the animal is a column of small pieces of bone are called the Vertebrae. There are two girdles round the body of which one gives attachment to the forelimb and is known as the Pectoral girdle. The other girdle which gives attachment to the hind-limb is called the Pelvic girdle. Both the forelimb and the hind-limb are formed of a number of bones

Skull or Cranium :

The skull at the posterior part consists of four bones which in the adult become completely fused with one another. The lowermost of these is the Basioccipital bone bounding the foramen magnum and forming the posterior or hinder part of the base of the skull. It has on the lower part two occipital condyles one on each side. The two ex-occipitals are found on the two sides of the foramen magnum. Each ex-occipital has a downwardly directed process called the Paroccipital process closely adhering to the swelling in front called the Tympanic Bulla. The Supra-occipital bone is placed above the foramen magnum. The middle segment of the skull consists of a bone at the floor of the skull called the Basisphenoid which is visible on the ventral side. On the two sides are the two Alisphenoids and on the dorsal side are the two Parietals. The Alisphenoid is produced ventrally into a Pteryoid process.

Skull-Dorsal view.

1—Premaxilla,
2—Nasal,
3—Frontal,
4—Zygomaticarch,
5—Jugal,
6—Process,
7—Parietal,
8—Interparietal,
9—Supraoccipital,
10—Squamosal.



Dorsally between the two Parietals is a small bone called the Inter-parietal. On the front are the two frontals and the two nasals.

The Pterotic bone lies in front of the ex-occipital. It has a swelling below called the Tympanic Bulla. Above and in front of it is the narrow squamosal. The squamosal articulates with the Frontal and Parietal and in front forms an arch called the Zygomatic arch.

On the ventral side is the Basisphenoid with Presphenoid in front. Anterior to the Presphenoid are the Vomers. Then come the Palatines. In front of the Palatines are the Maxilla and the Pre-maxilla.

Teeth :

The Guineapig has a number of teeth borne both on the upper and the lower jaw bones. They are ten in number altogether arranged thus :—

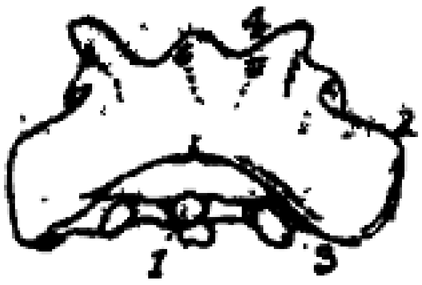
> On the upper jaw the two incisors are borne on each side of the bone. There being no canine there is a gap for its absence called the Diastema. Then the Maxilla bears one Premolar and three Molars on each side. The *lower jaw* or Mandible consists of two pieces called the Rami which are united in front by the symphysis. The upper or Alveolar border bears the teeth; posteriorly the process is called the Coronoid process. Behind it is the Condyle which fits into the Glenoid fossa. Below the condyle is the Angle. The dental formula of the Guineapig therefore is :—
>
> $$I\tfrac{1}{1}\ C\tfrac{0}{0}\ Pm\tfrac{1}{1}\ M\tfrac{3}{3}$$

The Vertebral Column :

The vertebral column is formed of a number of vertebræ which are named according to the region of the body as Cervical, Thoracic, Lumbar, Sacral and Caudal. Each Vertebra has a solid base called the Centrum. Each vertebra is separated from the other by an intervertebral cartilage except where the vertebræ have fused together. A typical vertebra has the following structure :—

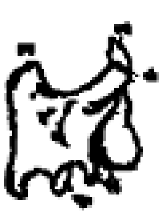
There is a solid base called the centrum. Two arches rise from the Centrum and are called the Neural arches, There is a process above the vertebra at the dorsal side which is called the Neural spine. And the cavity of the vertebra is called the Neural canal. Two processes project from the sides of the centrum and are called the Transverse processes. The vertebra has a flat process one on each side from the anterior part of the neural arch and are called the Prezygapophysis. They project upwards. On the posterior part from the neural arch there are two similar downwardly projecting surfaces called the Post-zygapophysis. The Pre- and Post-zygapophysis keep the vertebral column in position, *i.e.*, the post-zygapophysis of one vertebra articulates with the Pre-zygapophysis of the next vertebra.

Atlas



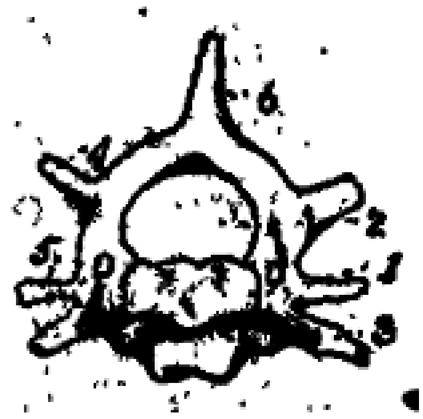
1—facet for process.

Axis



1—Transverse process,
2—Neural canal,
3—Process,
4—Pre. Zy.,
5—T. P.
6—Neural Spine.

Vertebra



Cervical Vertebrae :

These are seven in number, their spinous processes are short. The first vertebra is called the Atlas. There is no centrum in it. On the front part of this vertebra there are two concave articular surfaces for articulation with the condyles of the skull. The second cervical vertebra is known as the Axis. The centrum of this vertebra is produced anteriorly into a process called the

Odontoid process which goes inside the neural canal and articulates with the first cervical vertebra. The other cervical vertebræ have the typical structure.

Thoracic Vertebrae :

These are twelve or thirteen in number. These vertebræ are characterised by bearing ribs from their sides. The neural spines are tall and transverse processes are short. Each of the first nine vertabræ is provided with a pit on the under surface for the articulation with the tubercle of a rib. The hinder vertebræ become gradually like those of the lumber region.

Lumbar Vertebrae :

Thse are six or seven in number and are characterised by their larger size and bigger processes. They have no ribs.

Sacral Vertebrae :

These are three in number and are all fused together to form the sacrum which gives support to the pelvic girdle.

Caudal Vertebrae :

These are seven in number. They become smaller downwards and the last portion degenerates into a rod.

Ribs and Sternum :

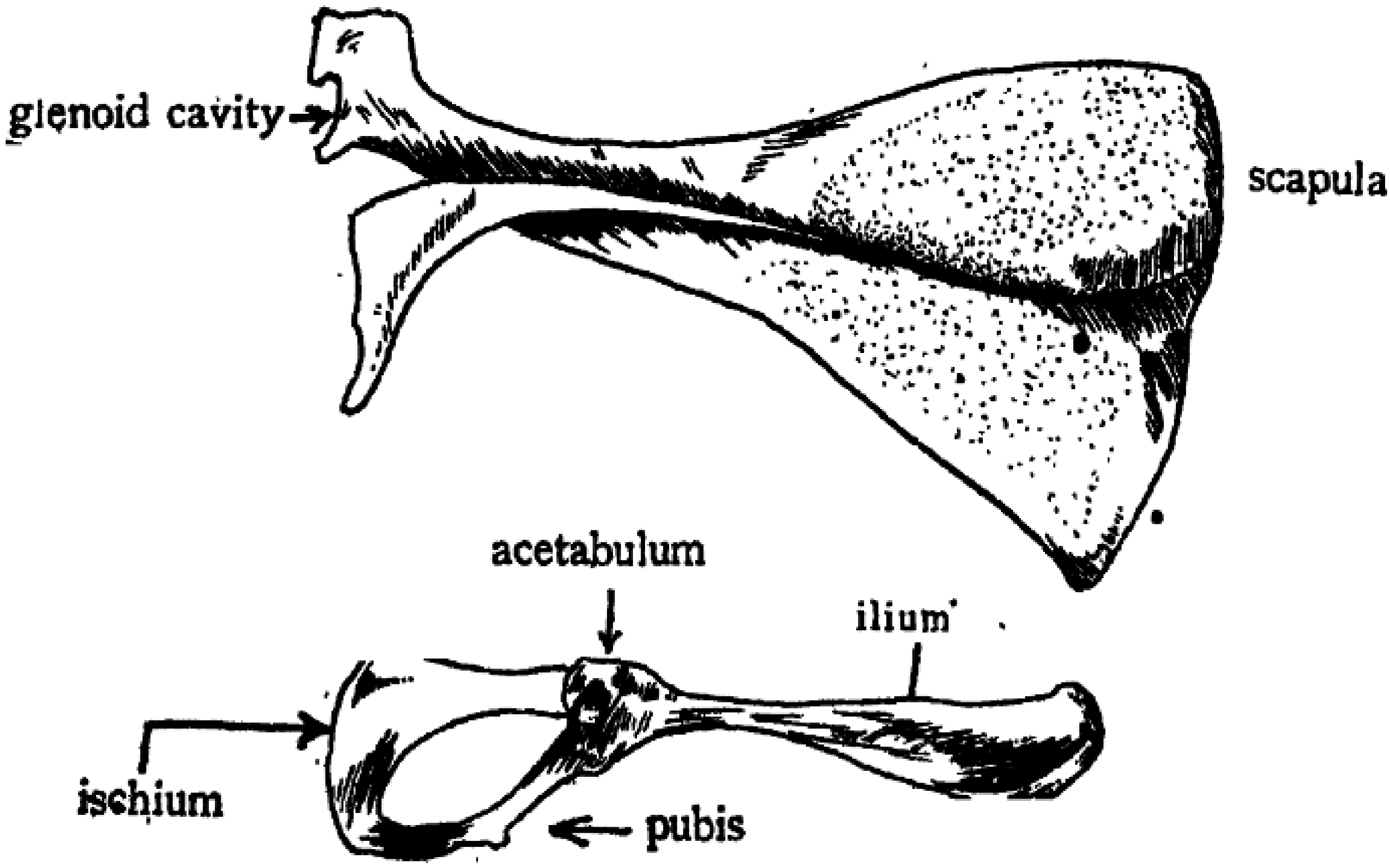
There are 12 or 13 pairs of ribs. The ribs are curved bony rods articulated with the vertebræ at the back and the first nine pairs are connected with the breast bone called the Sternum.

The portion of the rib connected with the sternum is called the sternal portion of the rib. The end which is connected with the vertebra is called the head or capitulum and there is a second articulation with the transverse process called the tuberculum. The first seven ribs are directly connected with the sternum while the 8th and 9th ribs are connected with the rib in front of them.

The breast bone is called the sternum. It has an upper portion called the manubrium. Next to it, 2 or 3 small pieces and finally the xiphoid process bearing the Xiphoid cartilage.

Pectoral Girdle :

The shoulder girdle practically consists of one bone called the Scapula. This is a flat triangular bone with the apex downwards. It bears a prominent external ridge called the spine which at its lower end becomes free as



Pectoral and pelvic girdles:

an acromion with a long backward metacromion. At the apex, is the cavity for the humerus called the glenoid cavity. There is a small process in front of the cavity called the coracoid process.

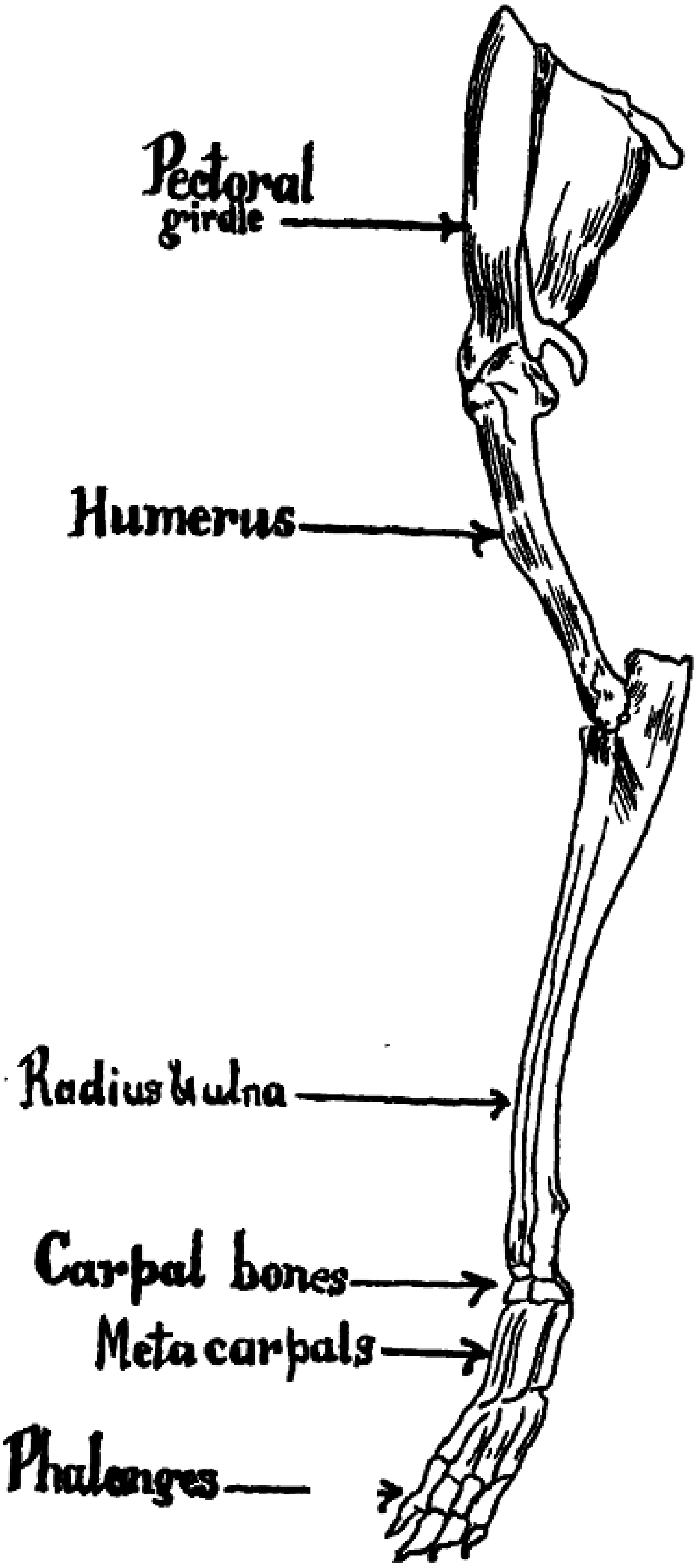
The clavicle or collar bone is a long, slender, curved bone between the acromion and the sternum.

Pelvic Girdle :

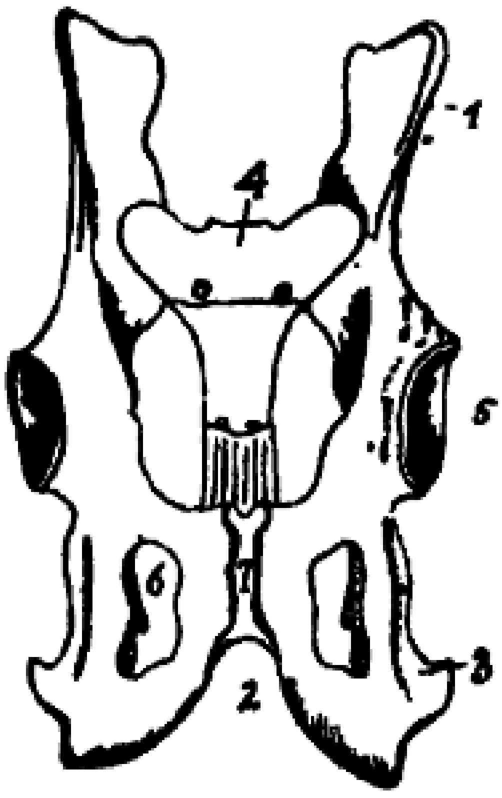
The hip girdle consists of two halves, each of which is known as Os innominatum. It forms a ring with the sacrum called the pelvis. Each Os innominatum consists of a dorsal ilium articulated with the sacrum, a posterior ischium and an anterior pubis. The two pubic bones combine to form the pubic symphysis. The ischium and the pubis are separated by a foramen on each side in front called the obturator foramen. There are two cavities on the two sides called acetabulum for the articulation of the hindlimb.

Forelimb :

The first bone which is articulated with the glenoid cavity is the humerus. It has a large head and separated by grooves are two processes, the first one is the greater tuberosity and the inner one is the lesser tuberosity. At the lower end is a pully-like trochlea, above which are two supratrochlear fossæ, the coronoid fossa in front and the olecranon fossa behind. Next, the two fore-arm bones are the radius and the ulna. The radius lies in front of the ulna. These two bones articulate with the trochlear surface. The ulna has a notch called the sigmoid notch and a process called the olecranon process. Then follows the wrist with seven carpal bones arranged in two rows. The proximal row consists of three bones called the scaphoid on the inner side, the semilunar and the cuneiform on the outer side.



Pelvic girdle.



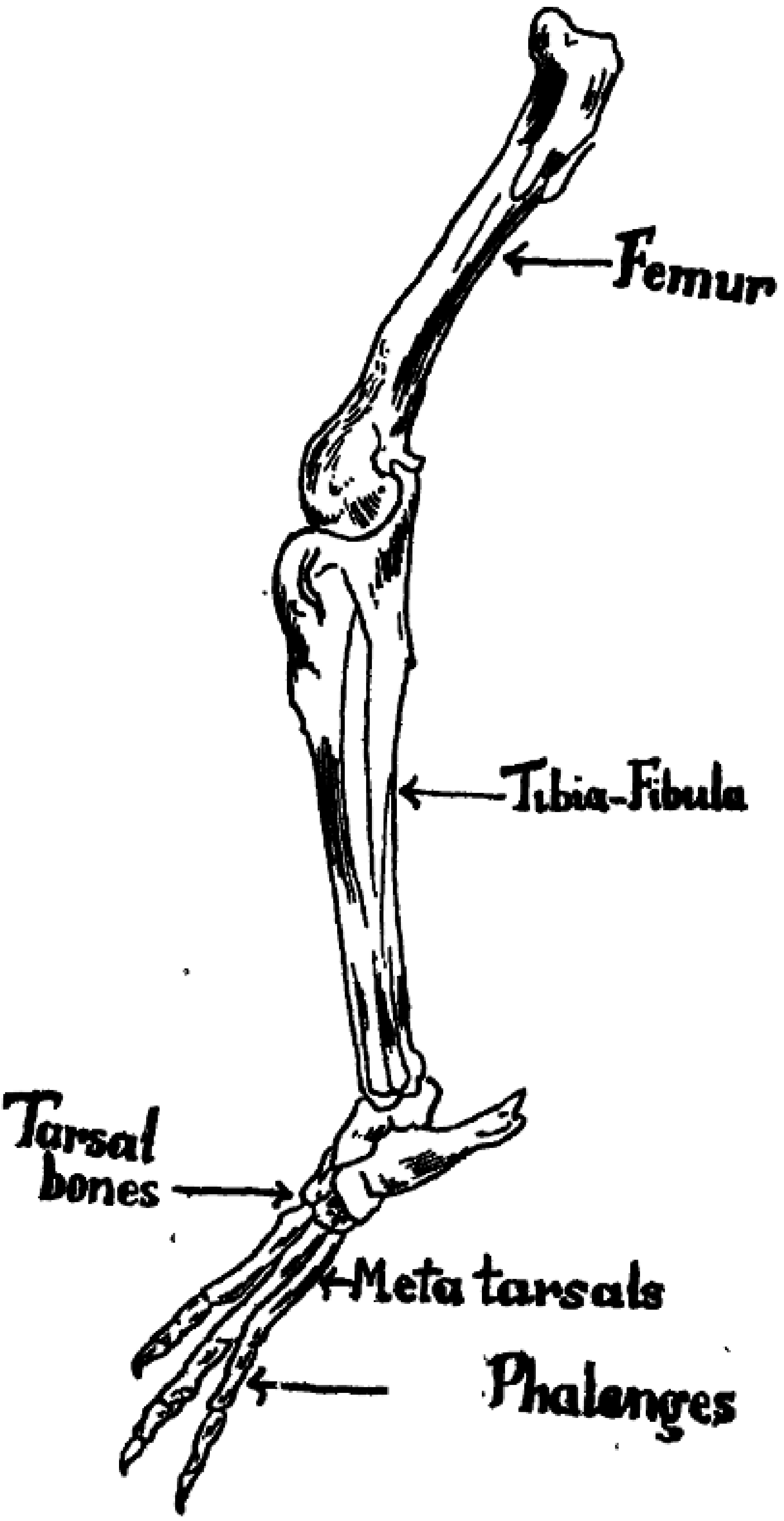
1—Ilium, 2—Pubic, Sym
3—Ischium, 4—Sacrum,
5—Acetabulum,
6—Obturator
foramen..

The distal row consists of unciform, carpale and the pisiform bones. There is another bone between the two rows. Then follow the four metacarpal bones bearing the four digits, with three phalanges in each. Each digit is clawed.

Hindlimbs :

The acetabulum gives attachment to the longest

Hindlimb.



bone of the body, the hip-bone or the Femur. It has a large head, below which are the three prominences, the greater trochanter on the outside, the lesser trochanter on the inner side and the third trochanter below the great trochanter. At the lower end of the femur are the two large condyles for the tibia. A knee-cap or patella covers the knee-joint and is connected by ligament with the tibia. The tibia and the fibula are the next two bones which are fused at the lower part. The fibula is a feeble bone by the side of the tibia. The tibia is a stout bone and bears the cnemial crest in front. The ankle like the wrist has got 6 bones arranged in two rows. The first row forms the heel and consists of two bones called the calcaneum on the outer side meeting the fibula and the astragalus on the inner side meeting the tibia. There is a central bone called the navicular. The distal row consists of three bones. There are three metatarsals bearing the three digits which are clawed. Each digit has three phalanges.

CALCUTTA UNIVERSITY QUESTIONS, 1935

BIOLOGY

FIRST PAPER

1. Describe a typical vegetable cell.
2. Describe the structure of a Pea seed and the mode of its germination.
3. Draw a diagram of a typical leaf and label its parts. What are the normal functions of the leaf.
4. What do you understand by photo-synthesis? Describe some experiment by which you demonstrate it.
5. What do you understand by alternation of generations in the life-history of a plant? Illustrate your answer by reference to the Moss plant or to the Fern plant.
6. Describe briefly the life-history of Mucor.
7. Some Yeast cells are put into a solution of sugar and kept in a warm place. Describe the changes that may take place in (*a*) the Yeast, and (*b*) the Solution.

BIOLOGY

SECOND PAPER

1. Describe the main differences between plants and animals.
2. Give an account of the life-history of Monocystis.
3. Draw a diagram of the reproductive system of Leech and label the various parts.
4. Draw the external features of Bhetki, and label the various fins and apertures.
5. Describe the arterial system of Toad.
6. Describe the pelvic-girdle of Guineapig.
7. State briefly Darwin's contribution towards the idea of Organic evolution.

CALCUTTA UNIVERSITY QUESTIONS, 1936

BIOLOGY

First Paper

1. What is protoplasm? Give a short account of the physical and chemical nature of it.
2. Give a short account of the different modes of cell division.
3. Draw a diagram of a typical flower and label its parts.
4. Draw transverse sections of monocotyledonous and dicotyledonous stems and label the parts.
5. Give an acount of the life-history of *Spirogyra*.
6. How does a plant respire? How would you demonstrate it?
7. Write short notes on—(*a*) conjugation, (*b*) oospore, (*c*) prothallus, (*d*) cotyledon.

BIOLOGY

Second Paper

1. Give an account of the main differences between the living and the non-living matter.
2. Describe the various structures of an *Amoeba*.
3. Draw and describe the nervous system of the fresh-water prawn.
4. Draw and describe the alimentary system of Bhetki.
5. Draw a diagram of a dissected heart of a toad, and label the positions of the various apertures and valves.
6. Compare the bones of a fore-limb with that of a hind-limb of a guinea-pig.
7. Give a few morphological examples by which you can show the evidences of organic evolution.

For Theoretical questions on Biology for 1937, 1938—See Practical Biology by T. C. Nandi.

Intermediate Examinations, 1939

BIOLOGY FIRST PAPER Full marks 75

1. Describe the main structure of a typical plant cell, and mention its differences from an animal cell.
2. Tabulate the main differences between respiration and carbon assimilation in plants.
3. What are the functions of roots?
4. Draw and describe a typical flower.
5. What is alternation of generation? Illustrate it from the life-history of a moss.
6. Describe briefly the life-history of Spirogyra.
7. Write short notes on any **four** of the following:—

   (*a*) *epigeal*, (*b*) aggregate fruit, (*c*) saprophyte, (*d*) xylem, (*e*) venation, (*f*) hermaphrodite flower.

Intermediate Examinations, 1939

BIOLOGY SECOND PAPER Full marks 75

What do you know of the theory of organic evolution?

2. Describe the structure of an amoeba.
3. Draw and label the various parts of the genital system of a leech.
4. Describe the alimentary system of Bhetki.
5. Describe the course of circulation through the heart of a toad.
6. Compare the external features of a toad with that of a guineapig.
7. Draw a diagram of the pelvic girdle of a guineapig and label the parts.

Intermediate Examinations, 1940

BIOLOGY FIRST PAPER Full marks 75

1. Give a brief account of the special characteristics of living objects, and compare them with those of non-living object. 15
2. Describe the structure of a pea seed and the mode of its germination. 15
3. What are the characteristics of a root? How is it distinguished from a shoot? 15
4. What is the utility of a leaf to a plant? What are stomata? 15
5. Compare a pea plant with a maize plant. 15
6. Describe briefly the life-history of mucor and show how it differs from that of a moss. 15
7. Write short notes on any **five** of the following:— 15

   (*a*) hypogeal germination, (*b*) phloem, (*c*) chlorophyll, (*d*) pollination, (*e*) stipules, (*f*) compound leaf, (*g*) parasite, (*h*) adventitious root.

Intermediate Examinations, 1940

BIOLOGY SECOND PAPER Full marks 75

1. Describe the essential structures of an animal cell.
2. Describe the method of movement (locomotion) of amoeba, hydra and leech.
3. Describe the vascular system of the freshwater prawn (Palaemon).
4. Write a brief account of the life-history of toad.
5. Draw and describe the red blood corpuscles of Bhekti, toad and guineapig.
6. Describe the formation of the three germinal layers in Gallus (fowl).
7. Write short notes on any **five** of the following:—

   (*a*) contractile vacuole, (*b*) alternation of generations (*c*) Botryoidal tissue, (*d*) Statocyst, (*e*) notochord (*f*) retina, (*g*) urostyle, (*h*) diastema.

1941.

BIOLOGY

1. Describe briefly the physical and chemical properties of Protoplasm. 15

2. Describe the different phases of Indirect cell-division

3. Describe and compare the structures of an albuminous seed with that of an ex-albuminous one. 15

4 What are the principal functions of the shoot? 15

5 What are the functions of the leaf? Distinguish between a *simple* and a *compound* leaf 15

[illegible] the different parts of a flower of *pea*, and mention [illegible] functions. 15

Describe the prothallus of a Fern. What phase does it represent in the life-history of the plant? 15

1941.

BIOLOGY Second Paper Full marks 75

1. Tabulate the differences between the invertebrata and the vertebrata. 15

2. Give the essential morphological characters and life-history of *monocystis*. 15

3. Describe the structures of the body wall of *hydra*. 15

4. Compare the modes of feeding of amoeba, hydra and leech. 15

5. Describe the arterial or efferent branchial system of Bhetki. 15

6. Draw the external features of toad and label the various structures including the apertures. 15

7. Make a drawing of the alimentary system of a Guineapig, and label the parts.

INDEX

Abdomen, 368.
Acacia, 144.
Accessory, 135.
Acquired character, 79.
Achene, 182.
Acropetal, [illegible].
Actinomorphic, 167.
Adhesion, 173.
Adventitious, 114.
Afferent, 311.
Aerenchyma, 207.
Allantois, 68.
Aestivation, 172.
Alae, 169.
Alimentary, 370.
Albuminous, 96.
Aggregate, 184.
Algae, 233.
Alternation of generation, 245.
Amphibia, 323.
Amnion, 68.
Amoeba, 253.
Anaerobic, 229.
Anabolism, 2.
Androecium, 1[illegible]
Angiosperm and
  Gymnosperm, 226.
Annelida, 270.
Annulus, 272.
Antheridium, [illegible]7.
Anus, 334.
Apogamy, 246.
Aorta, 340.
Apospory, 246.
Appendages, 282.
Archegonium, 242.
Arches, 340.
Artery, 291.
Axil, 124.
Atlas, 395.
Azygospore, 235.
Axis, 396.
Axon, 28.
Backbone, 251.
Bacteria, 225.
Bar. gill, 316.
Barbules, 265.
Banyan, 115.
Bile duct, 334.
Bicollateral, 213.
Biology, VII.
Bladder, 350.
Blastoderm, 64.
Blastula, 66.
Blood, 26.
Botany, 86.
Botryoidal, 273.
Body cavity, 271.
Body cell, 264.
Bone, 25.
Bract, 165.
Brain, 317.
Bronchi, 382.
Bryophyta, 225.
Bud, 137.
Bulbil, 136.
Bundle, 213.
Caecum, 372.

Calcium Carbonate, 195.
Calcium Oxalate, 201.
Calyptrogen, 207.
Calyx, 168.
Cambium, 215.
Canal, 369.
Cane-Sugar, 199.
Capitulum, 159.
Capsule of Sporogonium, 238.
Carbohydrates, 41.
Carotid, 340.
Carbon assimilation, 40.
Carpus, 325.
Carpel, 163.
Cartilage, 25.
Cell, 11.
Cell-division, 12.
Cellulose, 4.
Centrosome, 11.
Cerebellum, 388.
Cerebrum, 386.
Chemotaxis, 48.
Chiasma, 357.
Chlorophyll, 40
Chick, 64.
Chloroplast, 207.
Chromatin, 12.
Cilia, 237.
Circulation, 380.
Cloaca, 334.
Claw, 400.
Cladode, 130.
Clavicle, 364.
Closed bundle, 213.
Cleavage, 64.
Columella, 231.
Cnidoblast, 265.
Cnidocil, 265.
Compound leaf, 152.
Conjoint, 213.
Coelenterata, 261.
Coelome, 271.
Commissure, 300.
Conjugation, 231.
Conus, 338.
Coenocyte, 230.
Corpora quadrigemina, 388
Cotyledon, 92.
Columnae carnae, 375.
Colloid, 10.
Coracoid, 364.
Cross-fertilisation, 244.
Cortex, 213.
Cross-pollination, 178.
Cuticle, 215.
Culm, 130
Cutin, 194.
Cymose, 157.
Cystolith, 195.
Cytoplasm, 189.
Dactylopodite, 286.
Darwin, 80.
Dermatogen, 206.
Development of bird, 64.
Diaphragm, 372.
Didynamous, 173.
Diastema, 371.
Dicotyledon, 94.
Differences, 4.
Digestion, 3[illegible].
Digits, 366.
Diploblastica, 261.
Duct, 373.
Ductless glands, 383.
Duodenum, 372.
Ear, 359.
Ectoplasm, 11.
Ectoderm, 264.

Embryo, 64.
Efferent, 311.
Endodermis, 215.
Epidermis, 215.
Epiglottis, 381.
Encystment, 257.
Epithelium, 20.
Evolution, 70.
Endocrine, 335.
Endoplasm, 11.
Exalbuminous, 94.
Eye, 358.
Eustachian, 360.
Excretion, 36.
Eefmentation, 229.
Fallopian, 386.
Fat body, 336.
Fern, 240.
Femur, 367.
Fertilisation, 242.
Fins, 306.
Filament, 233.
Fish, 304.
Fission, 256.
Foot, 245.
Flower, 161.
Foramen magnum, 361.
Food-material 30.
Forelimb, 365.
Free cell formation, 19.
Frog (Ref. Toad), 324.
Fungi, 225.
Gametangia, 231.
Gametes, 234.
Gametophyte, 236.
Gamopetalous, 169.
Gametogenesis, 17.
Gamosepalous, 168.
Ganglia, 299.
Gonidangium, 230.
Gastric mill, 289.
Gel, 10.
Genital organs, 351.
Guard cell, 211.
Germinal, 17.
Gill cover, 315.
Gills, 316.
Girdle, pectoral and pelvic, 365.
Gland, 334.
Glomerulus, 350.
Glottis, 348.
Growth, 134.
Guineapig, 367.
Gullet, 333.
Gut, 333.
Gymnosperm, 226.
Gynoecium, 174.
Haemocoele, 271.
Haemoglobin, 314.
Hairs, 368.
Harderian, 390.
Helicoid, 138.
Heart, 310.
Hermaphrodite, 268.
Hirudo, 269.
Histology, 187.
Holophytic, 4.
Holozoic, 4.
Homologous, 156.
Hormone, 53.
Humour, 359.
Humerus, 365.
Hypodermis, 218.
Hyoid, 363.
Hydrotropism, 49.
Ileum, 334.
Ilium, 367.
Indusium, 241.

Inflorescence, 157.
Incus, 391.
Inheritance, 79.
Interstitial, 265.
Internode, 124.
Intestine, 334.
Invertebrate, 251.
Involucre, 157.
Irritability, 2.
Isobilateral, 222.
Jaw, lower and upper, 362.
Karyokinesis, 13.
Katabolism, 2.
Kidney, 350.
Labyrinth, 391.
Lamarck, 78.
Lamina, 141.
Large intestine, 372.
Larva, 303.
Larynx, 381.
Lateral branching, 138.
Lateral line, 305.
Laticiferous, 209.
Leaf, 140.
Leaflet, 151.
Leech, 270.
Legs, 288.
Life-cycle, 238.
Life-history, 351.
Limbs, 325.
Linin, 12.
Lungs, 349.
Male, 350.
Malleus, 391.
Mandible, 283.
Maxilla, 284.
Medulla oblongata, 354.
Meiosis, 17.
Meristem, 206.
Mesentery, 327.
Mesoderm, 270.
Mesophyll, 221.
Mesoglea, 261.
Metabolism, 2.
Metamorphosis, 352.
Metazoa, 249.
Mimosa, 142.
Mitosis, 13.
Monochlamydeous, 166
Monocotyledon, 108.
Movement, 47.
Mucor, 230.
Muscle, 328.
Musci, 235.
Mutation, 85.
Mycelium, 231.
Nares, 326.
Natural selection, 83.
Nematocyst, 265.
Nephridia, 275.
Nerve, 317.
Nerve cord, 300.
Nervous system, 299.
Neuron, 28.
Node, 123.
Notochord, 251.
Nucleus, 11.
Nucleolus, 12.
Nutrition, 30.
Obturator, 398.
Occipital, 361.
Oesophagus, 333.
Olfactory, 355.
Oosphere, 238.
Oospore, 238.
Organ, 20.
Ovary, 351.
Oviduct, 351.

Ovule, 176.
Ovum, 176.
Palate, 371.
Palisade, 221.
Pancreas, 373.
Parasite, 225.
Parenchyma, 221.
Parthenogenesis, 235.
Pea, 246.
Pectoral girdle, 364.
Pedicel, 159.
Peduncle, 159.
Penis, 385.
Perianth, 166.
Pericardium, 336.
Petiole, 142.
Phanerogam, 226.
Pharynx, 333.
Phellogen, 223.
Phloem, 208.
Photosynthesis, 40.
Pineal, 354.
Pisces, 304.
Plastid, 189.
Plant cells, 189.
Plumule, 93.
Pollen, 177.
Pollination, 179.
Polypetalous, 169.
Polysepalous, 168.
Portal system, 313.
Postzygapophyses, 323.
Prefoliation, 152.
Prezygapophyses, 323.
Primitive groove, 67.
Prosenchymatous, 197.
Protein, 8.
Prothallus, 242.
Protonema, 238.
Protoplasm, 7.
Protozoa, 253.
Protoxylem, 212.
Pseudopodia, 254.
Pteridophyta, 240.
Pubis, 367.
Raceme, 159.
Racemose, 157.
Rectum, 372.
Rachis, 159.
Reduction division, 17.
Regeneration, 304.
Reproduction, 56.
Respiration, 34.
Ribs, 396.
Root, 111,
Rostrum, 280.
Sacculus, 360.
Saprophyte, 230.
Scorpioid, 138.
Secondary cavity or Coelome, 271.
Secretion, 38.
Semilunar, 338.
Sense organ, 358.
Shoot, 123.
Sino-auricular, 337.
Skeleton, 361.
Spermatogenesis, 17.
Spermatozoid, 242.
Spine, 363.
Spirogyra, 233.
Spleen, 383.
Sporangium, 231.
Sporozoa, 257.
Spore, 241.
Sporozoite, 260.
Sporogonium, 238
Starch, 197.
Statocyst, 283.

Stem, 123.
Stimuli, 45.
Stomach, 372.
Stomium, 241.
Struggle for existence, 80.
Style, 174.
Sympathetic, 358.
Tadpole, 352.
Tail, 354.
Taproot, 114.
Teeth, 394.
Telson, 280.
Tendril, 144.
Tentacle, 261.
Tergum, 280.
Testes, 351.
Thalamencephalon, 354.
Thallophyta, 224.
Thorax, 369.
Tissue, 206.
Toddy, 228.
Torula, 232.
Trachea; 382.
Triploblastica, 270.
Tympanic, 360.
Unicellular, 228.
Ureter, 350.
Urinary bladder, 384.
Urinogenital, 385.
Urostyle, 364.
Vacuole, 12.
Vagina, 386.
Vascular bundle, 213.
Vas deferns, 384.
Vasa efferentia, 351.
Vein, 292.
Vena Cava, 344.
Venous blood, 347.
Venous system, 342.
Ventricle, 336.
Vernation, 153.
Vertebræ, 363.
Vertebrata, 251.
Verticillaster, 161.
Vexillum, 169.
Viscera, 332.
Vitreous, 359.
Vocal sacs, 331.
White of egg, 65.
Windpipe, 381.
Wolffian duct, 351.
Wood, 212.
Xiphisternum, 364.
Xiphoid, 397.
Xylem, 208.
Yeast, 228.
Yolk, 65.
Zoology, 249.
Zygapophyses, 364.
Zygomatic, 393.
Zygote, 58.
Zygospore, 232.